RIVER, ROAD, AND RAIL

Photo from Original Engraving by] [*Ciskit.*

OPENING OF THE GREAT EXHIBITION BY HER MAJESTY QUEEN VICTORIA, MAY 1ST, 1851.

[*Frontispiece.*

PPc-Descriptions

RIVER, ROAD, AND RAIL

SOME ENGINEERING REMINISCENCES

BY FRANCIS FOX

MEMB. INST. CIVIL ENGINEERS

WITH ILLUSTRATIONS

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DEDICATED TO

MY BROTHER

SIR DOUGLAS FOX

WITH WHOM I HAVE WORKED

FOR OVER FORTY YEARS

AS A TOKEN OF

MY AFFECTION AND ESTEEM

PREFACE

HAVING been requested by many friends to publish some reminiscences of my engineering experiences of the last forty years or more, during which period such rapid advances have been made in all parts of the world, I at last take up my pen. I hesitated for some time to do so on more scores than one, and was anxious to hide my identity by change of name and locality; but as this was found to be impossible, I now stand before my readers in my own person. I was also most desirous to avoid hurting the feelings of any one, and in this, I trust, I have succeeded.

I have told a simple, unconventional, and unvarnished story, every word of which is strictly true; and although I have endeavoured to use language of the simplest character, so that the youngest boy, whose aim it is to be an engineer, may understand it, yet I trust the facts given may be of sufficient interest to

attract the attention of boys of older growth, of whom I myself am one.

The narrative is of necessity discursive, and in some places disconnected; but this is, under the circumstances, inevitable.

I have had my ups and downs, my failures, and my successes; but if one thing more than another has been ingrained on my heart it is this: that to live happily one must ever strive to extend to all an open-handed sympathy, and to maintain through all the shocks and changes which life brings with it an unalterable purpose to reflect God's honour, and God's cause in the world, so long as life shall last.

F. F.

ALYN BANK, WIMBLEDON,
Sept. 1904.

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River, Road, and Rail

CHAPTER I

INCIDENTS IN LIFE OF SIR CHARLES FOX

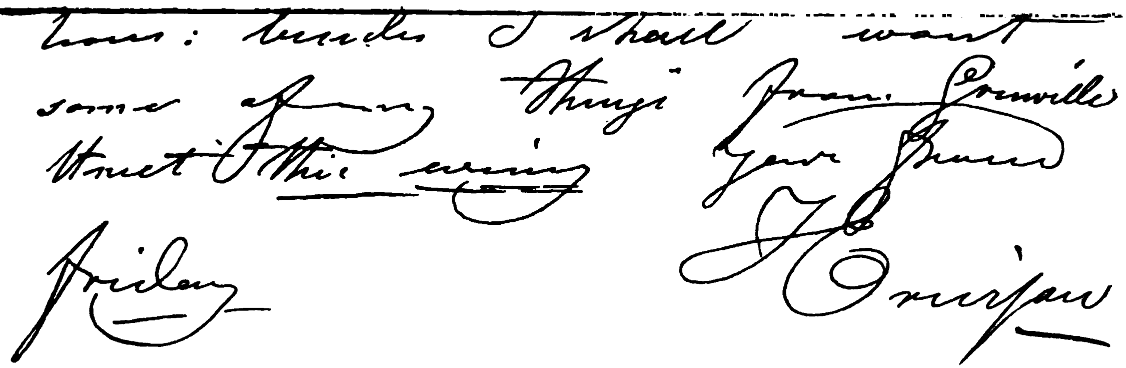
BEFORE giving an account of some engineering works and experiences, it may be interesting to place on record a few reminiscences of my late father, Sir Charles Fox. He was born in the Wardwick, Derby, in 1810, being a son of the leading physician and surgeon in that town, and had as his tutor for some years Mr. George Spencer, father of the late Herbert Spencer, the political economist. My grandfather intended that his son should follow his profession as a doctor, and consequently he worked in the surgery for two years; but in 1831 his keenness for railway engineering, which was then a new profession, induced him to abandon medicine, and he left

home for Liverpool. He obtained employment with Messrs. Fawcett, Preston & Co., and afterwards became associated with the well-known Mr. Ericsson, of "Monitor" fame, who was then designing one of the locomotives which eventually competed at the celebrated Rainhill trials. On that occasion my father drove the locomotive "The Novelty," which, but for the fact that it blew a tube, would probably have been the winner of the prize of £500.

For a time he took to locomotive driving, just as people in these later days take to driving motor-cars, and was regularly employed for some time on the Liverpool and Manchester Railway in that capacity: he had whilst there the trying experience of being present when the director of that company, Mr. Huskisson, was killed.

One dark winter's night he arrived in Liverpool with a level-crossing gate hanging on to the buffers, having, in the absence of signals in those days, run through the level crossing whilst the gates were shut across the railway.

It appears from a letter which I possess, and of which a facsimile is given, that Ericsson had his misfortunes, evidenced by the fact that he found himself "in a fairly comfortable bailiff's


tions: besides I shall want
some of my things from Grenville
Street this evening. Your friend
J. Ericsson
Friday

FACSIMILE OF LETTER FROM ERICSSON TO CHARLES FOX IN 1832, ANNOUNCING HIS ARREST IN LIVERPOOL.

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house in Liverpool," but nevertheless he had sufficient humour to make a pen-and-ink sketch of his window, showing the iron bars which imprisoned him.

My father became a pupil of, and afterwards assistant to, Mr. Robert Stephenson, who was then the engineer of the London and Birmingham Railway, now the London and North-Western.

Whilst engaged in the construction of the Watford Tunnel in 1834, he received instructions to go to Birmingham. He asked to be allowed to remain, for they were working in very soft and dangerous ground; but his request was declined, and he was sent to Birmingham. He had not been gone more than a few days when a message was received that the tunnel had fallen in, and eleven men had been killed. He immediately hurried back, and found that there was a panic on the spot. Up to this point is what my father himself told me, but a very old friend of mine further related that, when the tunnel had fallen in and had produced this panic, my father went to the works and said to the men, "That tunnel has to be put through, cost what it will, and

therefore I want you men to volunteer." Not one of them would do so. "Very well," he said, "I will do it"; and he got into the bucket, and was just about to be lowered down the shaft, when the ganger, using language more strong than elegant, said he "would not see the master killed alone." He went down with him, and these two finished the length through the dangerous ground, after which the men returned to work.

In 1837 Herbert Spencer entered the office at Camden Town as an assistant engineer to my father, and it was during this time that my father designed the present roof over Euston Station, the first of the kind ever made. He afterwards designed or built the large iron roofs of New Street Station in Birmingham, of the Great Western Railway at Paddington, and others at Waterloo Station, York, and elsewhere.

An amusing episode took place during his lifetime in connection with the completion of a certain railway in Ireland. The company fixed a day for the opening of the railway, notwithstanding a warning given by the contractor that

he would not allow it to take place unless his final account were previously paid. The company ignored the contractor, invited the mayor of the city to start the train, had a battery of artillery to fire a salute, and filled the special train with their friends, intending to take them to the other end of the railway, some twenty miles, where a luncheon had been provided. The mayor waved his green silk flag, the band struck up, the artillery fired a salute (bringing down the glass of the roof), and the train started, but only to be brought to a standstill by a man on the line waving his arms and shouting that the rock cutting had fallen in. The fact was, some hundred tons or more of rock had been blown on to the railway by a gunpowder blast, thus effectually blocking the line and rendering it impossible for the train to proceed.

The chairman was furious, and wished to arrest everybody concerned; and the visitors not being able to get to the other end of the line, the luncheon was duly consumed by the navvies. Late in the afternoon it was remembered that a full account of the opening, with all the speeches, had already been sent to the news-

papers. The secretary telegraphed to stop it being inserted, but the answer came back, "Too late—gone to press," the result being that a full account of the ceremony appeared next day in Dublin, although it had not taken place.

Here let me give an illustration of the inconveniences imposed on busy men by summoning them unnecessarily to courts of law.

On a certain occasion, whilst sitting in his office in Spring Gardens, a man walked into my father's room, and served a "subpœna" upon him, requiring his attendance at the assizes. He protested that he knew nothing of the case, but the man was insolent, and simply said, "To Chelmsford you'll go."

To Chelmsford therefore he went, and in due course was called, and sworn, to give evidence. He addressed the judge as follows: "My lord, am I not entitled to my fee and expenses before I give evidence?"

"Oh, certainly!"

The counsel said, "Sir Charles, you need not be uneasy about that; I will see you are paid." But he said that would not satisfy him; if they

insisted upon calling him as a witness, they must pay him there and then.

A little delay occurred before the necessary funds were produced; but having received them, the counsel, who was evidently nettled, said, "And now, Sir Charles, having wasted the time of the learned judge, of the jury, and the whole court, perhaps you will tell his lordship all you know of this case."

"Well, I know nothing," said Sir Charles, "for you have called the wrong man"; and having bowed to the judge, he left the court.

Amongst the many guests at my father's house in those days was the dear old Professor, Michael Faraday; and we had the privilege of attending his lectures at the Royal Institution. He, like all other lecturers, occasionally failed in his experiments; but, when this occurred, not only did he take the disappointment with the greatest good-humour, but he at once turned it to such good result, by investigating the cause of the failure, that we almost preferred that his experiments should occasionally fail.

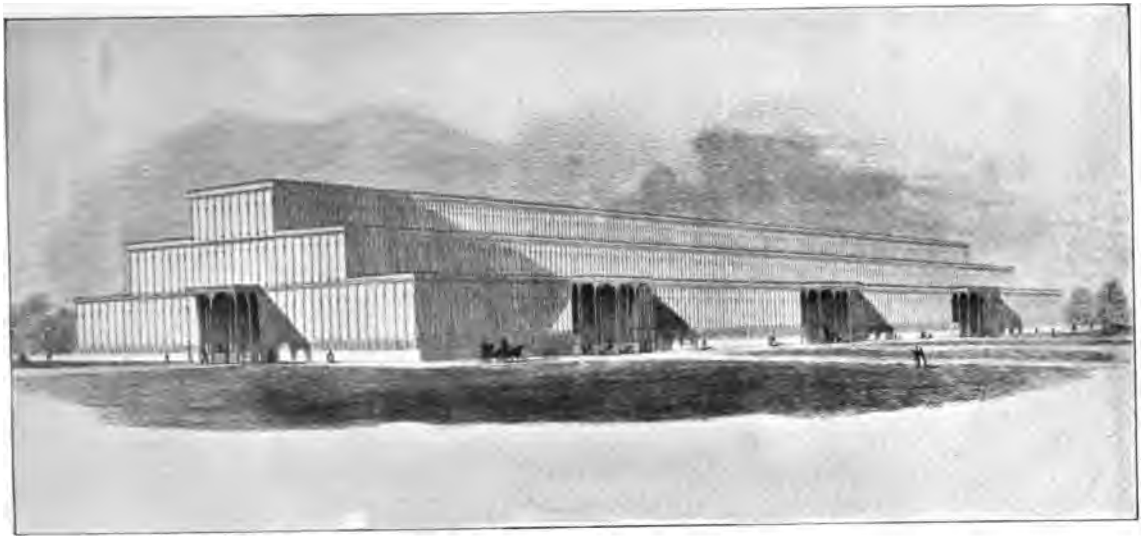
He used to play with us children, and many a time he was to be seen rolling on the drawing-room floor in a Christmas romp, or indulging in "hide-and-seek."

In the autumn of 1850 my father received the order for the erection of the Great Exhibition of 1851. The idea of a building of glass and iron was due to Sir Joseph Paxton, but the original design was not altogether a pleasing one, consisting as it did of a plain rectangular building.

When, however, it is remembered that no less than two hundred and twenty competitive designs were submitted for the building, it is a matter for congratulation that so light and fairylike a construction was the result.

It is impossible to give the names of all those connected with this great work, but amongst others appear those of Cubitt, Barry, Owen Jones, Digby Wyatt, Cowper, Cooper, and many others.

From the commencement it was decided that the building in all its various dimensions, the length, width, and height, should be multiples of 24, the girders being 24 ft., 48 ft., or 72 ft., and so arranged that any columns or girders taken



ORIGINAL DESIGN FOR GREAT EXHIBITION OF 1851.

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haphazard should be interchangeable. In fact, the system of standardization, at last being adopted in Great Britain and the Colonies, was carried to a high state of perfection in this structure.

My father and his then partner, Mr. John Henderson, suggested the introduction of the arched transept to cover the large elm trees which proved to be the great feature of the building. The contract was accepted late in 1850, and the Exhibition was to be opened in May, 1851; but, owing to the extreme novelty of the design, it was considered by most people that it was impossible to complete it in the time. My father had great confidence in cast iron if properly designed, and he became known as the "Cast-iron Man." No one but he was able to design the building as regards its details, and therefore upon him, personally, devolved the duty of drawing nearly everything, even to the most minute particulars. Eighteen hours a day was he at work at the drawing-board, and, so soon as a plan was pencilled in, he sent it to the drawing-office to be traced and put in hand in the pattern shop.

Although quite a boy, I visited the building during its erection nearly every day, and on several

occasions with the old Duke of Wellington. He was almost the only man who thought the work would be completed in time, and he used to pat my father on the shoulder, saying, "You'll do it yet."

Several amusing incidents occurred during the erection. One of the large trees in the park came exactly in the way, and would have effectually prevented the glass end of the transept being fixed. My father applied to the authorities for permission to cut it down, although two other trees were arranged to be enclosed in the building. No consent could be obtained, and a meeting was therefore arranged on the spot, when all who were interested attended, but the leading official ordered that the tree must not be touched.

My father turned to his foreman and said, "John, you hear what this gentleman says; on no account must this tree be cut down."

"All right, sir."

That night the tree was felled, and, when once down, could not be reinstated. A row of young trees also interfered with the building, and as no official consent could be obtained for their removal, private arrangements were made

for shifting them a short distance. All the joiners' benches were placed near them, and the ground speedily covered with a foot or more of shavings to prevent the movement of the soil being noticeable, and then one night all these trees were transplanted, being removed in a line the necessary distance to clear the building; but, as the Ordnance maps showed all these trees, the authorities were at a loss to understand how it was they were so inaccurately indicated on the plans.

An old wooden pump, for the removal of which permission was asked, an undertaking being given to replace it after the Exhibition was closed, was not allowed to be touched; and so it projected through a hole in the floor into the building itself, during the whole time the Exhibition was open to the public.

When the structure was well advanced, the glazing had to be commenced, and, so soon as any of it was fixed, it was essential that the whole should be completed as quickly as possible before any strong wind came, for, should half or three-quarters be glazed, there was always serious risk of the glass being blown out. Unfortunately this very thing happened, in spite of

all care; a very severe gale came on just at this critical time, and the effect was much the same as when one holds a thin paper bag with its mouth open towards a gale. The glass was blown out almost by the acre, and heavy loss was occasioned.

The structure was approaching completion when some one started the theory that, as it was intended to have music at the opening, an accident would be caused by the vibration of sound causing the glass to shake. Each pane of glass would take up its own responding note, and would consequently vibrate with such violence that it was predicted "the glass would come down in showers." It was therefore necessary to try the experiment so as to allay any fears in the public mind.

On a particular day, whilst the work was in full operation, hammering going on in every part of the building, Herr Reichardt, the well-known tenor, began to sing at one end of the building. Gradually the hammering ceased, and, as the song proceeded, silence prevailed amidst the whole audience of attentive workers, and at its close it was received with loud applause.

The full orchestra was then tried, and all the bass pipes of the organ groaned aloud in thorough discord, in the effort to shake out the glass, but not a pane moved, nor even responded. The Government authorities were invited to test the building in any way they thought fit, and it was in consequence of this that the Sappers and Miners (now the Royal Engineers) were told off to march "at the double" over a platform erected upon the girders.

The rhyme which I add as an appendix, based upon "This is the house that Jack built," appeared in 1851, and is worth recording.

I remember a letter about this time coming to my father addressed in the following somewhat vague manner: "To the bilder, what is bilding the bilding in I. Park"; but the Post Office authorities, with their usual ability, solved the problem, and the letter reached its destination.

A photograph of the opening, by Her Majesty Queen Victoria, of the Great Exhibition on May 1st, 1851, is given, in which the Prince of Wales, now our King Edward VII., known as "The Peacemaker," is shown standing on her

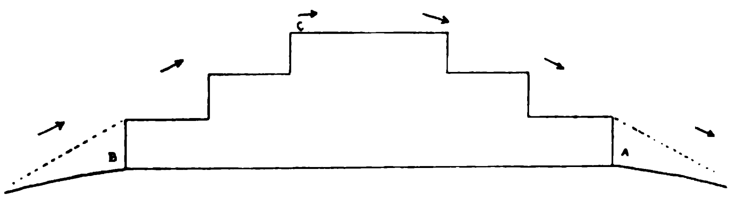
right hand: my father and Sir Joseph Paxton (the two left-hand figures in front with silk stockings) standing side by side.

When the building was removed by my father to Sydenham, to its present exposed position, it was again predicted that it would not stand—in fact, the leading authority on wind pressures of that day stated in public that, under the action of gusts of wind, "he could not entertain any belief that the building would endure for a long time." It is a curious fact that, if at any time a pane of glass is blown in, it is almost invariably on the leeward, or protected side.

Assuming that the wind is blowing in the direction of the arrows, it occasionally happens, in very strong gales, that a pane of glass, which probably has loosened, blows in. In such cases it is always about the point A, and blown *inwards*; and it is observed that no severe wind is felt at B, on the face of the building towards the wind.

The explanation of this is, that a triangular mass of quiescent air, as shown by the dotted lines, causes the gale to be deflected upwards and over the building; at the point C the full effect is felt. The wind then passing down clear

of the building, leaves another mass of quiescent air at A; but this is slightly rarified, and its barometrical pressure reduced by the drag of the gale. When a momentary lull occurs in the storm, this air regains its full barometrical pressure, and the increase is immediately felt by any loose glass at A.



SECTION OF CRYSTAL PALACE, SHOWING WIND CURRENTS.

My father has left his mark on every railway in the world; amongst his many inventions was the switch, which is now in universal use. Prior to this the ordinary sliding rail, as used by contractors to-day, was the only device; but it had this great disadvantage, that, if a train were shunted when the rail had been moved, it ran off the metals and was derailed; whereas with "Fox's patent switch" the train remains safe on the line.

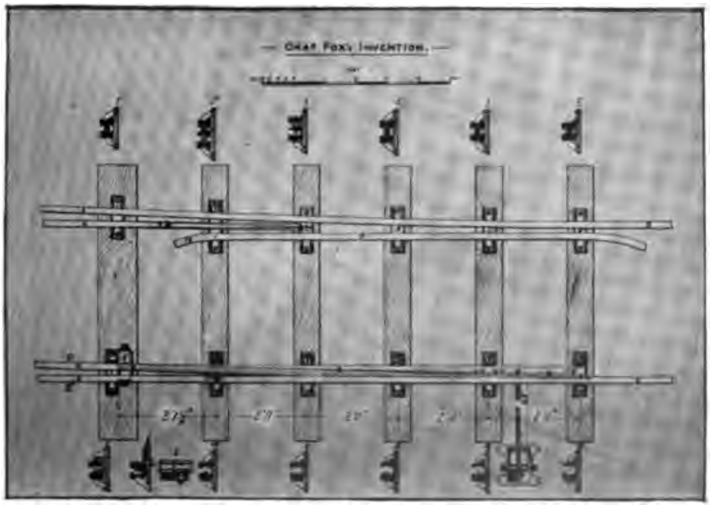
A photograph of his original design, dated 1832,

is given, in which only one "tongue" to the switch was proposed.

He was also the first engineer to adopt the cast-iron cylinder, or caisson, for the construction of bridge foundations in rivers, which is now of world-wide application.

One thing which strongly impressed me about my father in connection with his position as master towards his men was this: he laid it down as a maxim that he would never dismiss a man for an accident, unless it was due to downright carelessness. He used to say that the man, having been educated up to that point at his expense, would never commit the same blunder again, and consequently he was of more value to him than others. If this policy were more generally adopted, many a really valuable workman would be saved from social wreck, and the masters would be greatly benefited.

After many years of arduous and useful work my father died at Blackheath on June 24th, 1874, at the comparatively early age of sixty-four, his decease having been unduly accelerated by the effect of a serious accident.



THE ORIGINAL DESIGN OF THE SWITCH: 1832.

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CHAPTER II

EARLY REMINISCENCES

My first introduction to engineering was of a somewhat startling character, for on one of my visits to see the construction of the Great Exhibition of 1851 in Hyde Park, as already described, it being a very hot day, I sat down on a small seat, and fell fast asleep. It so happened this was what is known as a "boatswain's chair," used by the workmen in the erection of the ironwork, and some of the men amused themselves by tying me into it, and then hauling me up to the roof. When I awoke I was hanging in mid-air, much to their amusement, but somewhat to my own alarm.

It was on one of these visits that an incident occurred which impressed itself deeply on my mind, and the absolute truth of which I see as I grow older. A bricklayer, one of many, was engaged in building a brick pier about three feet

square and six to eight feet in height, and in his haste or carelessness he built it out of the perpendicular; it leant over to one side. My father, who was erecting the Exhibition, saw this with his ever-quick eye, and was walking up to the man, when he dropped his trowel, came to meet him, touched his cap, and said, "Please, sir, don't be hard on a fellow." "Well, you blockhead, why don't you build your work upright?" And he replied, with great truth, "Well, sir, you see, there are so many slants, but there's only one perpendicular."

And so it is all through life. How many wrong ways there are of doing a thing, but only one right one!

One of the earliest things that is necessary for an engineer to learn is the meaning of the word "contract," as, for the term of his natural life, he will never be beyond its reach. As I learnt it in a very practical way when I was only eleven years of age, I will mention the incident by means of which it came to be so firmly embedded in my memory.

I was sent to school to the Rev. Thomas Gascoigne, of Cavendish House, Sherwood, Notts, an excellent place; but, it being my first absence

from home, I naturally did not like it. The next term my younger brother, two years my junior, joined me.

An idea got into my head that my mother was seriously ill, and this completely unsettled me. I took into my confidence a "chum" named Gresley, afterwards a captain in the Royal Navy, and with his assistance I decided to run away home, 130 miles, taking my brother with me. I had put away in my writing-desk, in case of emergency, a sovereign, and this gave me the necessary means for carrying my plan into execution. The night before the event I managed to persuade the matron to give us our Sunday clothes and caps, and I noticed where our boots were kept during the night.

At 4 a.m. on the morning of the day Gresley woke us, and I at once dressed and persuaded my brother to do the same. The other boys in the room were very inquisitive, and would no doubt have got us into trouble had not Gresley, with an air of authority, told them to "shut up" and go to sleep.

Our intention was to catch the 6 a.m. train from Nottingham for London, and, as the school is three miles from the station we allowed an hour

to get there. Cavendish House is situated on the top of a hill, about two hundred yards away from the high road, which gradually descends into a valley and then ascends to Mapperley, a hill about a mile off, on the way to Nottingham.

We slipped out of the house at about 5 a.m., but were seen by some of the servants, who asked us awkward questions; but having managed to obtain our boots, we pushed through the hedge and so to the high road. I felt misgivings as to our catching the train, and still more so on reaching the top of Mapperley Hill, as I heard a chink on the road, and thought my one sovereign was lost. This necessitated a search which delayed us. I found the coin, but on looking back I saw a man on horseback just emerging from the school lane, galloping after us.

We had a start of a mile, but there were three-quarters of a mile to run before we could reach the outskirts of Nottingham, and unless we could do this our fate was sealed.

I was a good runner, and having taken my brother "in tow," we bowled along as hard as we could go, looking back anxiously from time to time at the approaching horseman.

We managed to reach the first houses, near the

Rock Cemetery, about fifty yards in advance of him, and at once dived down a narrow alley, which had posts at the entrance to stop horses, but whether it was a through passage or a *cul-de-sac* we knew not. Fortunately we were able to get through, and thus for a time shook him off. But it caused us considerable delay, as we had then to pick our way through the courts and alleys and back slums of Nottingham instead of keeping to the direct road. We got to the station at five minutes past six, and so missed the train, and found there was no other until eight o'clock.

I was puzzled in my mind what to do and where to hide, but had not a moment for hesitation, so I decided we must lock ourselves up in the first-class waiting-room, which we did, taking the key out of the lock,

We had brought with us a lump of cake, and this constituted our breakfast; but, whilst getting our meal, we heard the man trying all the doors and searching the station from end to end. He tried to open our door, but evidently concluded that it had been locked up for the night, and had not yet been opened, and so passed on.

At three minutes to eight I cautiously opened the door and looked out, and, not seeing our

dreaded enemy, I slipped into the booking-office and took one second-class ticket for London; as both of us were under twelve, the price was 17*s.* 6*d.*

We then made a rush for the train, and, just as we got into a second-class carriage, I saw the man beginning to search the train, commencing at the engine.

He at last came to our carriage, and then I thought nothing could save us. He rushed at my brother, but the latter got his arms wrapped round the leg of the seat, from which no power could stir him. Then he attacked me, and whilst defending myself and clinging to the window strap of the opposite door, the guard, hearing a disturbance, came up and inquired what was the matter.

"These young gentlemen," said the man, "have run away from school, and I have been sent to fetch them back."

"Ah! that's a bad job!" said the guard; "but let me see, have you got a ticket?"

To this I replied I had.

"Then," said he, "the company have entered into a contract to take you to London, and it's my duty to see it carried out," and, so saying, he

shut and locked the door, and, having whistled, off we went.

I had never before heard what a contract meant, but this practical illustration of the word taught me a good deal.

We duly reached London, and took a cab to our home in Portland Place, where we told the cabman to apply to the butler for his fare, as we had not sufficient to pay him ourselves.

We found our mother well, and busy in her studio.

After remaining at home three days, my father, who, in spite of all efforts to appear serious, was much amused, took us back again, and I remained five years more at the school, worked my way to the top, and became the headmaster's "boy."

Some twenty years later, when Mr. Gascoigne had retired, I called on him and gave him a full account of our escapade, which so interested him that he insisted on my dining with him that evening to celebrate the event.

CHAPTER III

SETTING OUT RAILWAYS

ONE of the most important branches of our profession as engineers has been the setting out of railways, and a short description of some of our methods and experiences may be found instructive and practically useful. We have had many amusing incidents in connection with this part of our work. On one occasion, when we were fixing the route of an intended railway in Essex, we overheard a remark which was the reverse of flattering. A stout woman, standing at the gate of her cottage garden, seeing the party of engineers, with their instruments and flags, gradually approaching her house from the fields beyond, called out to her daughter, "Maria, here come the surveyors: take in the clothes."

In deciding upon the route to be taken by a railway in England, or in any country of which good maps can be obtained, we commence by

From a Photo by] [*Russell & Sons.*

SIR DOUGLAS FOX.

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drawing a pencil line direct between the two places to be connected. The contour lines on the map, which indicate the height of the hills—100, 200, or 500 ft. above the sea, as the case may be—are then consulted, and the pencil line is altered approximately to such a position that the minimum of embankment and cutting is required. The Government or Ordnance "bench marks," shown by a crow's foot (↑), are indicated on the maps, and the actual heights above the sea are given in figures, whilst on the ground itself corresponding marks are to be found on the buildings, mile-stones, or gateposts, thus giving the engineer the most valuable information.

We were engaged in laying out a projected railway in Bedfordshire and Northamptonshire some years ago, and had prepared our Ordnance maps as above for use in the field. We knew approximately where the line would have to run, but now it was necessary to go along the actual route with our levels, theodolites, and chains for measuring, intending to fix exactly the position of the line to be finally adopted. We found that we should have to pass through one very large estate, the owner of which, blind to his true interests, was extremely hostile to the project.

We became conscious of the fact that our hotel was being watched, and, so soon as we put our foot upon the estate in question, we were warned off by the gamekeepers. Of course, the law being on their side, we had to obey, and each day our efforts to get across the estate were fruitless. Matters began to look serious, and we feared we should have to drop the line altogether, when a bright idea struck us. Three gamekeepers were patrolling outside the hotel, so we sent off one engineer and a man in the wrong direction, promptly followed by gamekeeper No. 1; then we sent off another engineer and a man, also in a wrong direction, and he in his turn followed by gamekeeper No. 2; a third decoy party, followed by No. 3, exhausted the supply of gamekeepers. All three parties were instructed to keep close to the estate all day, and to keep the respective gamekeepers well employed; and, so soon as they had all been disposed of, the real surveying party started off in the right direction, and obtained before evening all the information required to prepare plans and sections and reference numbers, thus defeating the aims of the very obstructive landowner.

On another occasion I had been instructed

by one of the main-line companies running into London to visit a certain district in the southern counties, in which fruit is largely grown, to ascertain the views of the property owners as to whether a railway would be acceptable to them or not. I had called upon all but one, and having been promised their cordial support, went, with a light heart and with full assurance of success, to call on the remaining owner, an oldish gentleman possessing some 2,000 or 3,000 acres. I was shown into his drawing-room, and the maid-servant took my card to him. After waiting some few minutes a lady came in, and told me that her husband was not very well, and was not yet down, but she being his wife would be glad to take any message up to him. I explained the object of my call, that a railway was projected through his estate, that it would be of the greatest value to his property, and that a station would be provided at the cross roads, thus giving him and his large fruit traffic the greatest possible convenience. She went upstairs, and after some delay returned, and said that her husband declined to see me, that he didn't want the railway, and would oppose it in Parliament to the utmost of his power; he wished me to report this to the company.

I promised I would do so, and retired; and although I did report the facts to the directors, I also reported that the remainder of the district was favourable.

I was again sent down, and this time to lay the line out, and to prepare the necessary plans and sections and estimates, and it was with some diffidence that I entered upon the estate in question. I had completed my work about halfway across, and was in the midst of a large strawberry field, when I saw an old man, whom I surmised must be the owner, coming across the land towards me. He came straight up to me; but, as neither of us knew the other, having never met, I was not sure who he was, nor did he, on his part, know me.

He said, "What are you doing here?" I replied, "I am taking the levels of the land." "Yes, of course you are—any one can see that; but what for?" I meekly replied, "For a railway." "For a railway! For a railway! Why, Mr. Fox, an engineer from London, called on me the other day, and I was so angry at the idea of a railway across my fields that I declined to see him. Well, I'll thank you to go off my property."

I tried to pacify the old gentleman, but it was simply pouring oil on the flames, and

consequently began to pack my instruments, feeling that I was beaten. However, I remembered the anecdote of Theodore Hook under somewhat similar circumstances, and decided to adopt the same tactics. I at once assumed a position of superiority, and said that the railway would undoubtedly come, and that in his own interest it would be well to have it located in such a position as would be most acceptable, or rather least unacceptable to him; and I offered to divert the line a quarter of a mile farther to the east if that would meet his views.

"Oh, you can divert it, can you?" said he: "that alters the case." "Of course I can," I replied, "if only I am spoken to civilly, but I don't like being treated like a poacher." He became almost apologetic, and finally gave me permission to continue the work. "Only," said he, "you tell Mr. Fox from me that I think it's bad manners for him to send you, knowing I didn't want a railway."

I quietly thanked him, and added that I would take care that Mr. Fox was informed of his views. He left me, but had not gone a couple of hundred yards before I noticed that his wife, whom I knew, was entering the field and walking straight up to me; and, if she recognised me as the arch-traitor

himself, her husband would very soon be acquainted with the fact, and what the result would be I hardly dared to anticipate.

I put up my collar, turned the brim of my hat down, and stooped to examine with unprecedented interest the inside of my theodolite box, whilst she came and stood within a yard of me. I thought she would never move, and momentarily expected her to speak to me, in which event I should have to reply, and then the murder would be out. But at last her patience gave way, and she followed her husband to the other end of the field, and I was undiscovered.

The line was deviated as promised, and has since been constructed, and has proved to be of considerable benefit to the landowners and public.

Again, some years ago I was sent for by a certain railway company to advise them in a matter of difficulty in which they unexpectedly found themselves. The centre line of the railway had been set out by their resident engineer, and unfortunately he had left his pegs standing some inches out of the ground. Considerable delay occurred in acquiring the land, and a speculative builder had quietly stepped in, bought the land on which the pegs had been left, and erected a number of

houses, a public-house, and a chapel exactly on the ground which would have been required for the railway.

On the plans authorised by Parliament a centre line is marked, and on each side, about 110 yds. distant, are shown parallel lines known as "limits of deviation." The ordinary public labour under the misapprehension that these limits of deviation are the extreme limits, beyond which no works may be carried out; whereas the fact is that the centre line may be moved up to the limits, even if the works extend beyond; only into land, however, duly scheduled. "A little knowledge is a dangerous thing," as our friend the builder found out to his cost. I went down to examine the place, and saw that for a considerable distance the centre line had been built over, practically blocking the intended railway, with the view to compelling the company to purchase the buildings at a most inequitable price. It was a case of "diamond cut diamond," and I at once set to work to find out how it would be possible to defeat this attempt at blackmail.

So soon as I appeared on the ground with my assistants, I found the builder awaiting my arrival, and all the inhabitants, men, women, and children,

turned out to enjoy the fun, and to see how completely the company had been checkmated. It was no good attempting to do anything that day; but the following morning, whilst I kept the inhabitants all much interested in my theodolite and flags on the *west* limit of deviation for hours, my assistant ran a hurried line of levels along the *east* limit of deviation, to ascertain if that route were at all practicable.

That evening at the hotel we laid the amended line down on our plans, and found that, instead of following the authorised centre line, we could, by altering it, avoid touching any of the flimsy mushroom growth of buildings which had been erected solely with the object of selling. We, in due course, applied to the Board of Trade for the necessary sanction to reduce to a small extent the radius of a curve, and having obtained their consent, the land was taken possession of and the line made.

The finale was amusing. The builder found himself baffled, and the owner of the land through which the deviation passed now thought his chance had come for making a large profit out of the company. He met by chance one of the engineers, whom, however, he did not know, in a

railway carriage, and, being rather the worse for drink, began to talk loudly to the passengers of his affairs. "A fine thing for landowners is a new railway company," said he: "they are so very green; they have come on to my land to escape my neighbour, but I'll make 'em pay for it. What d'ye think I gave for the land? Two shillings a yard. What d'ye think they'll have to pay me? Twenty shillings. That's what I call a good profit."

A few days later, when the arbitrator sat to arrive at the true value, this owner gave a pathetic account of how he was being most reluctantly deprived of his land, when just at that moment the engineer above mentioned entered the room, and the witness remembered how he had unbosomed himself to the very man of whom he was now trying to take advantage. The result was a complete collapse of his extravagant claim.

Another instance of a speculative builder overreaching himself occurred on some works we were carrying out near London. He had ascertained the position of the intended railway, and, being under the same erroneous impression that Parliamentary plans cannot be departed from, had hastily run up a long terrace of some twenty

badly built houses exactly along the centre of the line, thinking that the company would have to purchase them and that he would make a handsome profit out of them. We merely diverted the course of the line some 30 ft., and built the viaduct in front of his terrace, the trains being to this day on the level of the first-floor windows.

In November, 1862, I was one of a party from our Westminster office sent to survey the mud-banks of the estuary of a river for purposes of reclamation and railway.

The tide only leaves the mud for four or five hours, and we therefore had to go in boats down the river to our sphere of operations, and, so soon as the mud appeared, we commenced work. At the mouth of the river there is a beacon about a mile and a half from shore, and we rowed down, arriving there about 5 a.m., just as day was breaking.

The mud is so soft that no one can walk on it without mud-pattens, which are rectangular pieces of board about 12 in. wide and 15 in. long, and are tied on to the feet by cords; and, even with these pattens, the mud, except where the *Zostera marina* or long green hair-weed grows, is unwalkable.

We had two boats, six sailors, and four of our party, one of whom was Mr. Alder. We left the boats in charge of two men in the nearest creek, and proceeded with our work of surveying by theodolite and chain, and ot levelling.

We had been at work eight or ten days, and had reached our last few hours of surveying, when we found ourselves half a mile from shore, and a quarter of a mile from the boats, which, the tide being low, were out of sight.

Mr. Alder was a little in advance with a sailor carrying his theodolite, and had reached a portion of the mudbank from which the weed was absent. The weight of the theodolite forced the sailor into the mud up to his knees, and Alder went to help him ; but, as he pulled him out, he sank in himself.

Then both got in, and when another sailor went to help he also sank. By this time the mud had been disturbed and churned up, and one by one each of the party going to the rescue was engulfed, until finally all eight of us were fast, like so many flies.

I at once realised that the situation was very serious, for we were all sinking, each too far oft

to assist his neighbour: the tide was rising, and the boats were beyond hailing distance.

I made a desperate effort, and, being the lightest one of the party, I succeeded in drawing one foot and then the other out, notwithstanding the great suction on the pattens. Then, by rolling on the surface of the mud until I reached the green weed, I found myself free, and started off to the boats for assistance, pacing along over the mud at my greatest speed.

So soon as I arrived within call I shouted to the men to bring everything they could lay their hands upon—oars, boathooks, bottom-boards—and to come with all speed to the rescue.

On reaching the distressed party I found matters serious enough. Alder had nearly disappeared, nothing but his head and one arm being left. The others were all in various conditions of sinkage, most of them up to their waists.

I at once threaded an oar under Alder's arm, and then gave something to each of the others to support them whilst we endeavoured to rescue him. Poor fellow! he was very exhausted, and had given up all hope of being saved, feeling convinced that, the mud being so soft, no "fulcrum" could be found for raising him again.

I rigged up a platform round him of oars and bottom-boards; the legs of the theodolite and level were unscrewed and used, as also the level staffs, and we found that, by thus distributing our weight over a larger area, we were able to exert sufficient force to lever him out; and at last we raised him to a standing position on the platform.

A more pitiable object can hardly be conceived, for he was one mass of black mud. We squeezed as much as we could out of his coat sleeves and legs of his trousers, scraped the worst of it from inside his waistcoat, and lightened him as much as possible.

To make matters more difficult, he could hardly stand, and we had somehow or other to get him to the boats. By placing oars or bottom-boards as stepping-stones a yard apart, we were able to help him on for a short distance, and then these had to be moved forward again; by which means at last we reached the boats, and at once sent him off with one of the sailors to the town, to be put to bed. We then returned to the rest of the party, and extricated them one by one.

Although much fatigued, we all realised the necessity of finishing our survey at once, as otherwise the whole work of the previous days

would be lost ; every man therefore volunteered to do this, and we accomplished our task.

But a great difficulty then arose from an entire absence of note-books, or even old letters, upon which to enter our observations and measurements, all of us having, before starting, carefully emptied our pockets of everything that might be injured by the water and mud, and Alder had carried off the necessary books with him.

Naturally I turned up my coat, intending to use my linen cuff, on which I frequently enter my notes, but found I was wearing a flannel shirt. Our hopes sank, and we almost gave up our work as lost, when fortunately I thought of my linen collar, and this I used as a note-book for the remainder of the day.

Twenty-two years afterwards this affair on the mud was the talk of the seafaring people of the place, for, had I not been able to extricate myself, the whole party would have gradually sunk overhead, and would have been literally lost in the mud.

CHAPTER IV

DIVING AND SUBAQUEOUS WORK

A VERY important branch of engineering, and one which has given opportunity for the display of the greatest ingenuity and high scientific knowledge, is in connection with subaqueous work. The great difficulties attending this have been surmounted by the determination of various pioneers, many of whose names are lost, but to my late friend John Gorman, of the firm of Siebe, Gorman & Co., we are indebted for much of the advance of recent years.

The original method, where the foundation of a bridge below water level was required, was to form a cofferdam of two rows of timber piles driven deep down, the space between them being excavated and filled with puddle clay; the water was then pumped out from the foundation, and the pier built. The diving-bell and diving-dress have since been introduced, and are in many cases employed,

whilst the caisson and cylinder, with or without compressed air, are very generally adopted.

In the case of the foundations of Westminster Bridge diving-bells were largely used, but the work was slow and tedious. For some time this was inexplicable, until at last the cause of some of the delay was discovered. It was found that so soon as the bell entered the water, and the men inside were securely cut off from observation, a pack of cards was produced, and many an exciting game was played on the bed of the river. Soon after this the diving-dress came in for more general use; but even that is liable to abuse, for, on a hot summer's day, there is no more comfortable place to get a good sleep than on the bottom of the sea, with your helmet on a rock for a pillow, especially if you realise that two men are grinding away at the air-pump, whilst another man has hold of your air-tube and life-line.

The greatest depth to which a diver ever descended and came up alive is 204 ft., whilst 100 to 120 ft. is the maximum depth at which work can be safely carried on.

A source of great danger in sea-diving is the possibility of entanglement of the air-tube and life-line, preventing the diver's return to the

surface. An engineer, a friend of mine, was once engaged on a pier in India, and he with two divers were working below. The men in charge of the life-lines continually received signals from the men below to pay out more rope and tube. This they did until it was all paid out. But the signals were due to the rushing of the water through the ironwork of the pier, and were not sent by the divers. The result was that the air-tubes and life-lines floated away with the current, and got almost hopelessly entangled with the staging and ironwork. The divers knew nothing of this until they endeavoured to return, when they found themselves caught. One man got alarmed, cut his life-line, slipped his leads, and came up to the surface like a cork; but the rapid change of pressure killed him. My friend kept his presence of mind, and quietly worked back along his line, disentangling and placing it in coils round his neck. Yard by yard he got it back, and in an hour's time succeeded in reaching the surface, completely exhausted.

On one occasion I had been invited by an engineer friend to accompany him in a submarine walk on the bed of the sea round a breakwater. I intended to have done this during July, but it

was October before I could get away from London, the result being that a gale had been blowing, and the sea was rough.

However, we decided to dive, and having put on thick flannels over our ordinary clothing, and red diving-caps on our heads, we were rowed across the harbour to the diving-barge. A good heavy sea was rolling in, and the boat was disagreeably lively. The barge was no better, for although moored fore and aft by the side of the breakwater, it had a very uneasy motion, and it took us all our time to get dressed, although each of us had a man to act as "lady's maid."

First one gets into a complete rubber suit, made without seams, all in one piece; then heavy boots are put on, each having 14 lb. of lead on the soles; then the metal collar, and finally the helmet, which weighs 30 lb. Two lead weights, each of 40 lb., are placed over the shoulders, one being on the chest, the other on the back; and thus accoutred with a total weight of 160 lb., we had to step over the gunwale of the barge on to the ladder, by no means an easy or a safe task. When breast high in the water the eyepiece is screwed on, and a tap being given on the helmet

by the man who holds your life-line and air-pipe, you descend.

My friend went down, and I followed him a few minutes later; but when below the surface, I found the sea so rough that I decided it was not prudent to proceed farther.

I decided to return, and came up the ladder, put my head out of water, and tapped at the eyepiece. The attendant unscrewed it and asked what I wanted. "Want!" said I, "I've had enough of this; the motion of the sea is intolerable!" "Oh! bless you, sir, go down below: so soon as you are on the bottom you'll be all right—there's no motion down there."

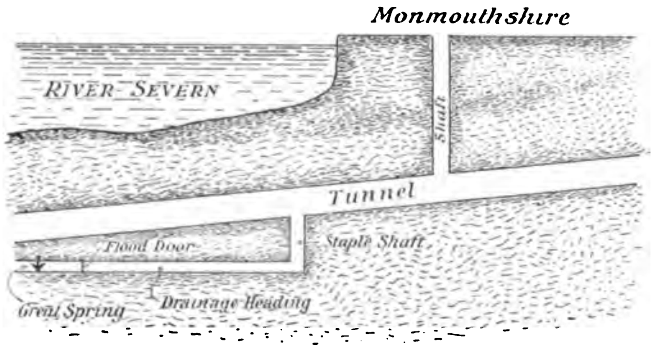
But I stuck to it that I must come out, and did so, my feelings being better imagined than described. The men signalled to the engineer, who came up and asked what they wanted. "Mr. Fox has returned." And he replied, "I don't wonder at it; besides which, the water is so thick with mud and sand one can see nothing." Thus ended our diving for that day.

A most remarkable case of diving occurred in the Severn Tunnel during construction. The drainage heading had been driven some considerable distance from the Monmouthshire shaft and

a flood door had been provided, so that, in case of any influx of water, the door could be shut by the men on their retreat, and thus time for attaining safety would be given.

The main tunnel had been also driven some distance, and a "staple" shaft to connect the

SECTION OF SEVERN TUNNEL.



tunnel and drainage heading had been made, and provided with ladders.

Suddenly the "Great Spring" was tapped, yielding some 27,000 galls. per minute, and drove the men out of the "heading." In the hurried scramble to get out they forgot to close the door. The men escaped, but the "feeder" was of such magnitude that the pumps were

overpowered, and the heading, then the tunnel, and finally the shaft were filled up to the level of the water in the Severn.

For the time being the tunnel works were lost, and all that was visible of them were the few feet at the top of the shaft. The door had to be shut, but how was it possible to be done? The distance was too great for any diver to descend, dragging his air-tube and life-line with him.

Recourse was had to Mr. Fleuss and his diving-helmet. This contains a supply of oxygen, with an arrangement of caustic soda for absorbing the carbon dioxide given off by the diver, and requires no air-tube; but, as Mr. Fleuss did not know the tunnel, it was impossible for him to go down. Lambert, the well-known diver, although strange to this helmet, courageously volunteered to make an attempt, and descended. The tunnel was blocked with floating timber, trucks and tubs, rails and heaps of bricks. He had to go down the shaft, then walk in absolute darkness down the tunnel to the staple shaft, which was no easy matter to find, and which he had to descend, and then had to walk along the drainage heading, a total distance of 400 yds., in order to reach the door.

Those only who are acquainted with diving can realise what this meant. The mere losing of the sense of locality is bad enough; but, added to this, the pitch darkness, the terrible loneliness, the depth of the water, the distance to be traversed, and the powerlessness of any help being given, were sufficient to cause the bravest heart to fail.

He went down, was absent an hour, returned, and had failed. He was induced to make a second attempt, the pumps being worked to the utmost capacity during his absence, but no lowering of the water was observable. He was away so long that it was feared he was lost, when suddenly the water in the shaft began and continued to fall, showing that he had succeeded, and had shut the door and had thus excluded the "Great Spring."

This act saved the tunnel, which was soon cleared of water; additional pumps were provided, sufficient to deal with the "feeder," and the Severn Tunnel to-day is a monument not only to the skill of the engineer and to the energy of the contractor, but also to the indomitable pluck of Lambert the diver.

An admirable method of excavation under

water is by means of the hydraulic jet. This, when working in soft material and in the hands of an experienced diver, using very high pressure water, effectually clears away all before it.

In putting in the foundations for Rochester Bridge in the year 1851, the late Sir Charles Fox made use of iron caissons for the first time under compressed air. This had been proposed by Dr. Potts, but had never entered the region of practical devices. The foundations were difficult, owing to the existence of the remains of a Roman bridge, which had to be removed, below the bed of the river. The operation would have been very costly had it not been for this system. The caisson acted as a diving-bell, being filled with air, compressed so as to equalise the hydrostatic head, and, by means of an air-lock, the men were able to enter and leave, and the material passed in and out, without losing the air and its pressure. So soon as the cutting edge had got through the ancient masonry, the cylinder without warning suddenly sank and nearly crushed the men within, between the bed of the river and the ceiling of the caisson, but the air inside was compressed to such an extent as to hold the cylinder up, and prevent such a catastrophe.

Since Rochester established the great advantage of cast-iron caissons, they have been adopted all over the world—in some cases being made of brickwork instead of iron, with a view to further economy. As a matter of fact, brick wells have been used in India from a remote date for founding piers of bridges. Caissons are not only used with compressed air, but are often open-topped, so that the water rises and falls inside with the tide. Excavation is then carried on inside by grab or diver, and, when the full depth is reached, concrete in cement is lowered to the bottom in "pigeon trap" boxes, and spread by the diver. This, when set, renders the caisson water-tight, and it can then be pumped out and the work carried on in the dry.

Sometimes a caisson, in sinking, gets caught up on one side by a boulder, or some other obstruction. This, in silt or sand, can be removed in a very simple and at the same time beautiful manner, as was done in the case of the Hawarden Bridge.

The Hawarden Bridge over the River Dee, a few miles below Chester, provides the widest opening for passing vessels of any bridge in Great Britain—namely, 140 ft. At this point on the

HAWARDEN BRIDGE, ACROSS THE RIVER DEE (OPEN).

Opening span, 140 feet.

[*To face p.* 48.

river no foundation but quicksand is to be found, a boring having been put down over 100 ft. indicating nothing better on which to found the bridge.

The well-known song beginning with the words "Mary, call the cattle home" refers to these treacherous sands of Dee; and to this day, if a vessel gets stranded on the sandbanks by the falling tide, the first thing the skipper does is to send the crew to bed, so that nothing should move on board, and thus tend to sink the vessel into the silt.

A serious flood occurred in the River Dee just as the sinking of the large cylinder, 43 ft. in diameter, was commenced. This cylinder consisted of a circular wall of brickwork-in-cement 5 ft. in thickness, provided with a steel cutting edge at the bottom. The whole thing had tilted over some 5 ft., and the chairman of the company unfortunately visited the work the next morning. He was much disconcerted, and expressed the opinion that we could never recover it, and that it was, in fact, lost. I asked him to come again in two or three weeks, and meanwhile not to be uneasy, as I knew a method by which it could easily be rectified.

The rough sketch shown on opposite page will explain what was done.

An iron pipe 2 in. in diameter, with a nozzle at the end, was lowered into the bed of the river close to the obstruction, the pipe being attached by a hose to a powerful steam-pump. The water issuing from the jet rendered the silt or sand "quick" beneath the obstruction, which rapidly sank away and the cylinder righted itself.

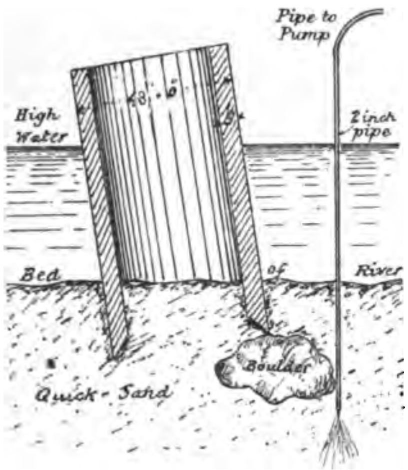
By means of such a water-jet, this cylinder of brickwork, 43 ft. in diameter, weighing 2,500 tons, and which had canted over to such an extent as to cause dismay to many, was brought back into position within three-quarters of an inch of its desired place in a few hours, and it was possible to play with this great mass. and move it one way or the other exactly as one wished.

When it had attained its full depth of some 70 ft. the interior was filled up with concrete, and the bridge girders built in place. The bridge was opened by Mr. and Mrs. Gladstone, and, in connection with the ceremony, an amusing incident occurred. Mrs. Gladstone, standing on the daïs, was requested to touch an electric button, which would put into operation the engines which open and close the swinging span of the bridge. This

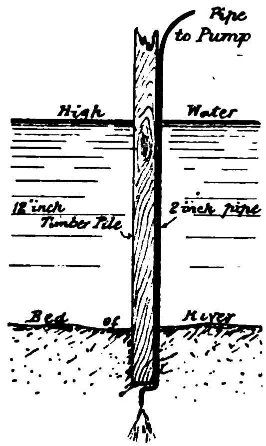
HAWARDEN BRIDGE, ACROSS THE RIVER DEE (CLOSED).
Opening span, 140 feet.

[*To face p.* 50.

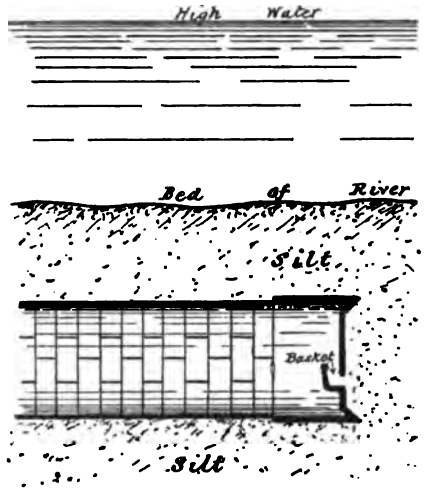
Use of Water-jet for removing Obstruction under Caisson.



Use of Water-jet for sinking Piles in Sand.



Tunnel under River.
with Greathead Shield & basket.



she did, and instantly the bridge began to move under the action of the powerful hydraulic machinery provided for the purpose; but, when Mrs. Gladstone asked to be shown what the particular mechanism was which she was supposed to actuate her attention was directed to the man standing on the gallery of the tower, as shown in the illustration facing page 48.

The arrangement for working the engines from the daïs had failed at the last moment, and the only effect produced by the electric button was to inform the man in charge of the engines in the tower, by means of an electric bell, as to the exact moment at which he was to put the machinery into operation. Having done this, he came out on to the gallery to watch the effect.

The water-jet is also of the greatest value in sinking timber or iron piles for bridges or pier foundations. To drive piles into sand requires very heavy blows, and the sand soon becomes, by impact, as hard as rock, and the piles receive injury; but by the water-jet they can be sunk 25 to 30 ft. in two or three minutes, and they can be moved in any direction required, so long as pumping is continued; when this ceases the sand in a few minutes settles round the pile and

grips it tightly. By adopting this process it is unnecessary to point or shoe the piles; they can be cut off square to begin with, and it need not be said that, for stability and security, a square-ended pile is far better than one that is pointed.

Another remarkable application of the use of compressed air is in connection with tunnelling by means of the shield. It is extraordinary how tunnelling in the silt of a tidal river, within six feet of the bed, can be carried on with safety and regularity. In fact, engineers can now almost bore a hole in water itself, and line it with iron, the result being a complete tunnel.

By working with a closed shield, fitted with the "basket," which acts as a water seal, it is possible to do the excavation in front almost entirely by the hydraulic force of the shield itself; but when a "blow-out" of air occurs, followed by an inrush of silt, the phenomena are such as to strike terror into the hearts of all but the most courageous and the most experienced.

The physiological effects on those engaged in compressed air are not yet fully understood, but enough is known to show that all sudden alterations in pressure must be avoided; and a very

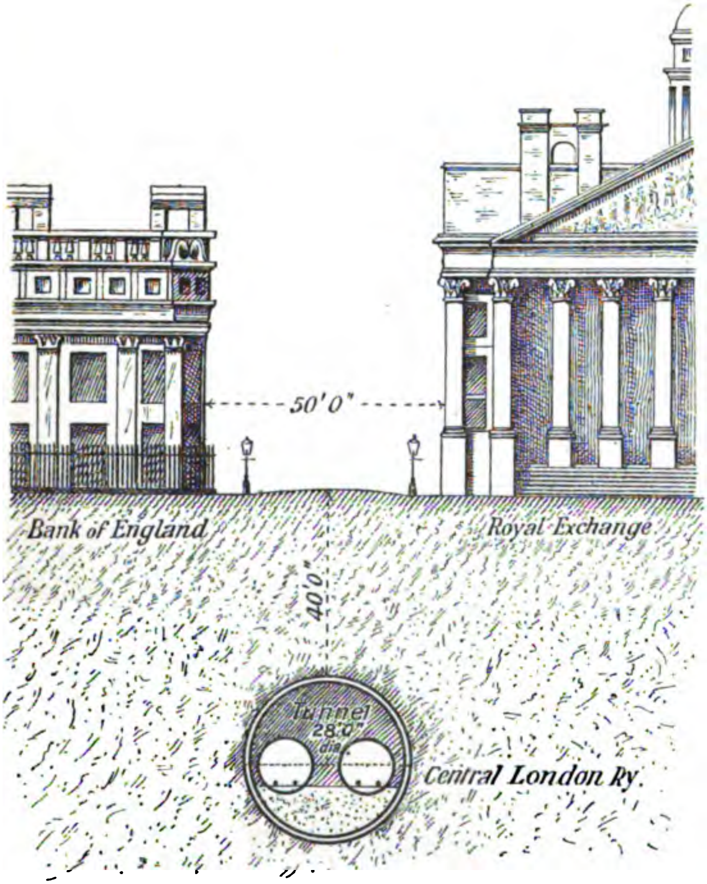
large volume of air, amounting to as much as 160 cubic ft. per minute for each man in the shield, is necessary.

When working in air under pressure, on entering the lock, the air is absorbed by the blood, carrying with it any gaseous impurities in its constitution; and, consequently, if it be at all high in carbonic acid gas, the blood receives that impurity. In coming out of the compressed air, as is well known, it is of great importance to be locked out slowly. The physiological reason for that could be best illustrated by the difference between opening a bottle of soda water rapidly, by taking the cork straight out, and letting the pressure off slowly at the mouth of the bottle. If it be let off slowly, the gas escapes almost imperceptibly; whereas, if the cork be taken out rapidly, the gas is liberated in large bubbles at once. It is well known that blood in the presence of air tends at once to coagulate; and recent investigation of certain cases which had occurred in the deep sinking of cylinders at Newcastle and elsewhere showed that, when the pressure was taken off, and the globules of air were formed, the same tendency was for the blood to coagulate. Where deaths had occurred, and post-mortem

examinations had been made, the veins and arteries had been found filled with coagulated blood, consequently producing death. If the pressure were allowed to pass away slowly, this risk was reduced: the danger lay in the possibility of the formation of a clot in the system.

In the construction of the Central London Railway a very remarkable work was carried out, under Sir Benjamin Baker and Mr. Basil Mott, which is worth recording.

In the narrow space, only 50 ft. in width, between the Royal Exchange on one side of Threadneedle Street, and the Bank of England on the other, it was necessary to drive a tunnel 28 ft. in diameter at a depth below the surface of about 40 ft. to the top of the work. To have attempted to do this by ordinary tunnelling would probably have wrecked both buildings; but, by the adoption of compressed air of 20 lb. to the square inch, a support was given to the sides, the roof, and the floor, equivalent to innumerable invisible props, and the work was carried out and completed, not only without the slightest knowledge on the part of the public, but without the smallest crack or other indication in either of the buildings.



THE CENTRAL LONDON RAILWAY UNDER THREADNEEDLE STREET.

When tunnelling under heavy pressure of superincumbent clay, with perhaps a tidal river 100 ft. in depth of water overhead, and Atlantic liners and battleships floating above you, it is difficult to describe the feelings of those in charge of the work, when the timber bars and baulks begin to sag under the weight, and it becomes necessary still further to reduce their strength by adzing away the lower sides of them, in order to get in the full thickness of brickwork. On such occasions as these, it is needless to say, the anxiety and strain on the engineer's mind are only equalled by the strain on the timber.

CHAPTER V

TUNNELLING

Before describing the methods of modern tunnelling, it may be well to refer back to ancient times to see what was done in days as early as 600 B.C.

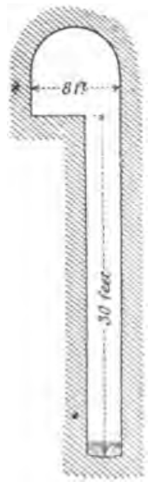
It is said that a tunnel was constructed under the River Euphrates at Babylon, and, in consequence of the city being built on both banks, it was necessary for them to be connected together. High walls, penetrated by occasional gates, surrounded the city and lined each of the banks of the river. The gates (a pair of the grêat hinges of which can be seen in the British Museum) were closed at night and during war; and a tunnel was constructed below the bed of the river by means of what is technically known as the "cut-and-cover" system. For this purpose the river was temporarily diverted from its course so that the excavation could be made in the dry bed, open to daylight. The walls and arch were then

built, the ground restored, and the river allowed to resume its former course. The tunnel is said to have been 15 ft. in width, 12 ft. in height, and built of brick.

Herodotus gives an account of the diversion of the river into a great excavation or artificial lake 40 miles square, and states that the besieging enemy, so soon as the water was drawn off, entered into the city by the river bed. It is believed that this same excavation was made use of for the construction of the tunnel. It is, however, desirable to state that doubts have been thrown on the subject, and it is possible that it may have to be relegated to the realm of mythology.

The next instance of a tunnel is that referred to by Herodotus in the Island of Samos; and it is satisfactory to know that, although very considerable doubts were expressed as to the accuracy of his statements, recent investigations prove that he was exactly correct. The description given by him, when expressed in English words and figures, is as follows: "They have a mountain which is 910 ft. in height; entirely through this they have made a passage, the length of which is 4,300 ft. It is, moreover, 8 ft. high, and as many wide. By

the side of this there is also an artificial canal, which in like manner goes quite through the mountain, and though only 3 ft. in breadth, is 30 ft. deep. This, by the means of pipes, conveys to the city the waters of a copious spring."

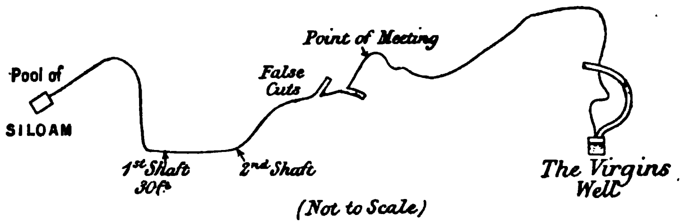


CROSS SECTION OF THE AQUEDUCT OF EUPALINOS IN THE ISLAND OF SAMOS.

The commentators on this passage say that Herodotus must have made a mistake, but the Rev. H. F. Tozer, in his book "The Islands of the Ægean," p. 167, gives the results of a personal visit.

He says the tunnel is 7 to 8 ft. in width; that two-thirds of its width is occupied by a foot-

path, the other third being a watercourse, 30 ft. deep at one end. He and other writers consider that insufficient allowance was made for the fall of the water, and the water channel had to be deepened. To describe it in more modern language, the resident engineer evidently made a mistake in his levels, necessitating a



TUNNEL FROM POOL OF SILOAM.

much deeper excavation than was at first anticipated.

Another and, if possible, a more interesting instance of tunnelling is that described in the "Proceedings of the Palestine Exploration Society," in connection with the Pool of Siloam, made by Hezekiah, B.C. 710: 2 Kings xx. 20.

About 710 B.C. a tunnel was driven from the spring to the well by actual tunnelling, the work being commenced at the two ends and by shafts, and the workmen met in the middle. The tunnel

was only 2 ft. in width and 3 ft. in height, except at the probable point of meeting, where the height is 4 ft. 6 in. The length is 1,708 ft., and there is a fall of 1 ft. in this distance. About the middle of its course there are apparently two false cuts, as if a wrong direction had been taken; but possibly these were intentional, and provided passing-places for the workmen and material.

On the soffit of the tunnel is carved an inscription, of which the following is a translation:—

"Behold the excavation. Now this had been the history of the excavation. While the workmen were still lifting up the pick, each towards his neighbour, and while 3 cubits (4 ft. 6 in.) still remained to cut through, each heard the voice of the other, who called to his neighbour, since there was an excess of rock on the right hand and on the left. And on the day of the excavation the workmen struck, each to meet his neighbour, pick against pick, and there flowed the waters from the spring to the pool 1,200 cubits (1,820 ft.), and 100 cubits (151 ft.) was the height of the rock over the head of the workmen."

Mr. Clemens Herschel, the well-known hydraulic engineer of New York, gives a most interesting

account in his book, "The Water Supply of the City of Rome," by Frontinus, of the report made by the Water Commissioner to the Emperor Trajan, A.D. 97, and with his kind permission I append the following.

A tunnel was being driven through a mountain from the opposite ends, the intention being to meet in the middle; and the following extract from the report of Nonius Datus to the magistrates of Saldae will best describe what occurred :—

"After leaving my quarters I met with brigands on my way, who robbed me even of my clothes and wounded me severely. I succeeded after the encounter in reaching Saldae, where I was met by the governor, who, after allowing me some rest, took me into the tunnel. There I found everybody sad and despondent. They had given up all hopes that the two opposite sections of the tunnel would meet, because each section had already been excavated beyond the middle of the mountain, and the junction had not yet been effected. As always happens in these cases, the fault was attributed to the engineer, as though he had not taken all precautions to ensure the success of the work.

"What could I have done better? I began by surveying and taking the levels of the mountain; I marked most carefully the axis of the tunnel across the ridge; I drew plans and sections of the whole work, which plans I handed over to Petronius Celer, the Governor of Mauritania; and, to take extra precaution, I summoned the contractor and his workmen, and began the excavation in their presence with the help of two gangs of experienced veterans—namely, a detachment of marine artillery and a detachment of Alpine troops. What more could I have done? Well, during the four years I was absent at Lambaese, expecting every day to hear the good tidings of the arrival of the water at Saldae, the contractor and his assistant had committed blunder upon blunder. In each section of the tunnel they had diverged from the straight line each towards his right, and had I waited a little longer before coming, Saldae would have possessed two tunnels instead of one."

Nonius Datus, having resurveyed the work, caused the two parallel tunnels to be united by a cross tunnel (*a b*) so that the waters of the river could finally pass through the mountain; and their arrival at Saldae was celebrated with

Aqueduct Felix, Rome.

Portion of lead pipe showing the oval section and joint in the lead.

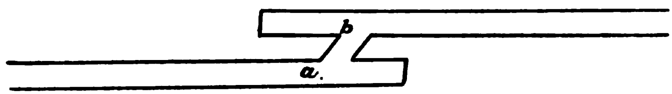
Aqueduct Felix, Rome.

Portion of the original lead pipe with the name of the aqueduct cast upon it.

[*To face p.* 66.

extraordinary rejoicings in the presence of the governor, Varius Clemens, and the engineer.

Whilst upon the subject of these Roman aqueducts the accompanying photographs of old water-pipes will be found interesting. One is a portion of a lead pipe from the Aqueduct Felix, which crosses the Roman Campagna, and it will be noticed that its cross-section is pear-shaped. These pipes were made by bending lead plates of

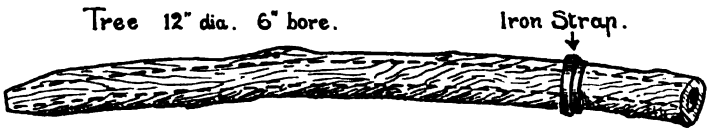


TUNNEL AT SALDAE.
The two "headings" missed and were then connected by crosscut *a b*.

the proper width and some 10 ft. in length into a pear-shaped cross-section, then soldering the longitudinal joint, the solder used being pure lead. The next is a portion of wooden water-pipe, used for the supply of London some two or three hundred years ago, long lengths of which were uncovered in the neighbourhood of St. John's Wood during the construction of the Great Central Railway.

It was a puzzle to know how these latter pipes,

consisting of tree trunks, could possibly be bored round a curve as shown below; but it is believed to have been done in the first instance by a drill, one inch in diameter, fixed on a pliable spindle, and this followed the line of least resistance, viz. along the central pith; then a larger drill was used, which again followed the course of the previous bore, and so on until the full required diameter was obtained. These tree trunks were



CURVED WOODEN WATER-PIPES, MADE OF TREES, DUG UP IN MARYLEBONE.

tapered at one end, and hollowed out at the other, so as to form a joint, an iron strap being provided to ensure a tight connection being made between them. Elm was generally used, and the quality of the timber is as good in many cases as on the day it was put in position.

We need not go very far to find instances of such an error as inaccurate meeting in tunnels; but there is one well-known case on an important main line in the Midland Counties, where the

SECTION OF WOODEN WATER-PIPE: 4 IN. BORE.

[To face p. 68.

engineers failed to meet, and to this day reverse curves exist in the tunnel to overcome the defect.

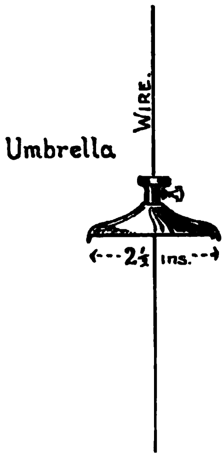
To attain this accurate meeting in tunnels fine wires are hung down the shafts, with heavy plumb-bobs suspended from them in buckets of water, or of tar, to bring their oscillations to rest; the true direction being given by means of a theodolite or transit instrument on the surface.

The wires are capable of side movement by means of a delicate adjustment, and are gradually brought exactly into the same vertical plane: hence, if they are correct at "bank," or surface, they are bound to be also correct below ground. The engineers below have to drive the galleries or headings so that only *one* wire is visible from their instrument: so long as one wire exactly eclipses the other wire, the gallery is being driven in the right direction.

As regards accuracy in levels, this is done by ordinary levelling; but it will be seen at once how much depends on care being devoted to both these operations.

Assume two shafts, 1,000 yds. apart, between which a gallery has to be driven; and, allowing a distance of 10 ft. between the wires, which are $\frac{1}{40}$th in. in diameter, an error of the diameter

of the wire at the shaft will cause a mistake of nearly 4 in. at the point of meeting, or of $7\frac{1}{2}$ in. if a similar error occurs at the other shaft in the opposite direction. The trickling of water down the wires increases their diameter so appreciably, and therefore conduces to further inaccuracy, that it is found necessary to fix a small shield or umbrella on the wire to deflect the water.



UMBRELLA ON TUNNEL WIRE TO PREVENT INACCURACY CAUSED BY WATER TRICKLING DOWN.

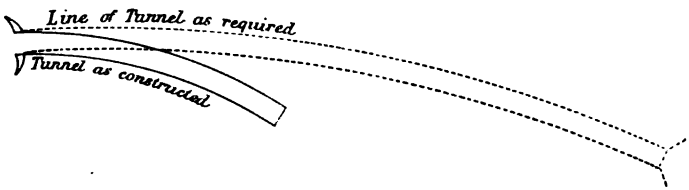
Some years ago a tunnel which had been commenced, but not finished, had to be completed. The first thing done by the engineers was to make an accurate survey of the then condition of the work—the rough sketch on opposite page indicates what was discovered. The explanation given by the former "ganger" was that he found the rock too hard, and he thought that by bearing round somewhat to the right he might get into more easily excavated material!

Where shafts cannot be sunk exactly on the centre line of a tunnel, in such cases as under

streets or rivers, the difficulty in accurate driving is greatly increased.

In the case of the Mersey Railway, neither of the shafts was on the centre line, and it was only by the utmost care of the engineers employed on the work that such an accurate meeting was attained under the centre of the river, the error being only $1\frac{3}{4}$ in.

When the wires were hung down the shaft, it



ERROR IN ALIGNMENT OF TUNNEL.

was sometimes almost impossible to prove that they were not touching, and consequently being deflected from the true vertical line by some rope or pipe, staging or timber, in the shaft. To overcome this an electrical current was passed down the wire, a galvanometer being in circuit. If the wire proved absolutely silent, and no deflection was obtained in the galvanometer, the conclusion could be safely drawn that the wire was hanging freely and truly.

In driving the necessary adit or heading for drainage purposes beneath a subaqueous tunnel, a rising gradient from the shaft bottom of 1 in 500 is allowed, to enable the water at the "face" to flow away from the workmen to the pumps in the "sump" or shaft bottom, otherwise the men would be working up to their waists in water; and it was for this reason that a similar gradient has been adopted in the case of the Simplon Tunnel.

When the heading is driven sufficiently forward to justify the commencement of the main tunnel, a fresh difficulty presents itself. This main tunnel has to be driven downhill, and consequently the water collects at the working face A: the bottom cannot therefore be removed until a bore-hole is put down from A to *a*. When this is done the remaining excavation can be taken out, and a further length of tunnel driven to B. A bore-hole is now sunk from B to *b*, whilst that from A to *a* can be plugged up: and thus the tunnel is gradually advanced.

By the adoption of the Greathead shield much of this difficulty can be avoided; but one subaqueous tunnel through water-bearing strata, at considerable depth, is sufficient for a lifetime.

From a Photo by] *F. A. Cooper.*

IN TUNNELLING COSTUME, 1883.

[*To face p.* 72.

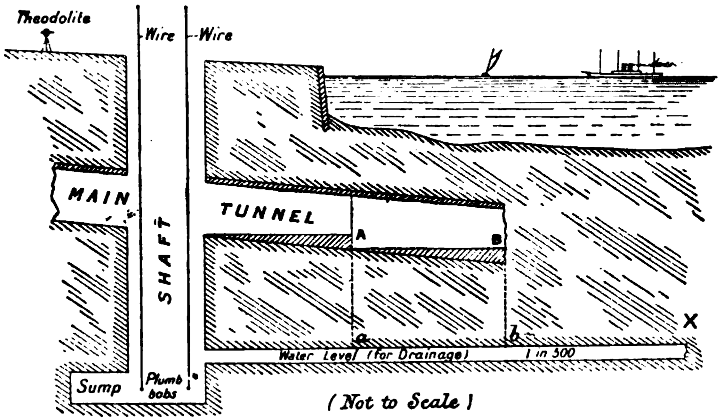
As an illustration of the danger to which men are exposed in such work, it is stated, with much regret, that in a certain tunnel, every precaution being ordered by the engineers, but neglected by the workmen themselves, all the men engaged in driving the drainage heading, by means of a tunnelling machine, died, the result of dust choking the lungs; and in the case of the first Vyrnwy tunnel crossing under the River Mersey —driven by Greathead shield under pressure— the mortality was great, in this instance being due to the action of compressed air upon the system.

When we were driving the drainage heading from Birkenhead to Liverpool, the question of what would be the maximum quantity of water to be pumped was of the greatest importance, and one very difficult to answer.

The sketch below may serve to illustrate the state of things. The strata dip from west to east, as shown in an exaggerated scale by the dotted lines. The shaft was sunk, and as each bed or layer of fissures was cut a large quantity of fresh water, not salt, was tapped, these fissures or beds cropping out inland.

When we drove the drift, we cut these same

beds again, thus drying up the shaft, but encountering the water at the lower level. The driftway was driven on a rising gradient, as already explained, of 1 in 500, to enable the water to flow down to the sump, and thus to be pumped away. As we continued to drive



LONGITUDINAL SECTION SHOWING METHOD OF CONSTRUCTING A TUNNEL UNDER A RIVER.

onwards, the water increased so rapidly that it became a serious question whether we should be successful; and on the visit of some friends to the works they found the resident engineer and myself sitting under a large umbrella hung from the roof of the driftway, calculating whether, if the same ratio of increase in quantity of water

were continued in proportion to the distance driven, we could ever get through.

The conclusion we came to was, that if the water increased every 100 ft. as it had done in the last 100 ft., no pumping power could grapple with it. But fortunately, on reaching the point marked X, where we cut the first bed which cropped out into the river, and where we feared we might encounter salt water, the quantity proved to be very small, and we found that in course of ages the river had practically filled up all the fissures with clay; and from this point onward the ratio of increase rapidly diminished.

In 1881, on my way back from Ireland, I visited the North of England, where we were carrying out some heavy work, and our resident engineer, James, asked me to stay with him at his lodgings. I was loth to do this, as I always preferred to stay at the Railway Hotel; but not liking to refuse my friend's invitation, I accepted.

On my arrival he apologised for having to give me a small bachelor's room; but being indifferent to this, and very tired, I went to bed early, he having informed me that the only occupants of the house besides ourselves were the landlady, who was a widow, and two maids.

On entering my room I found it was quite small—in fact, a dressing-room; and I noticed that it had two doors, neither of which had a key. One door led into an adjacent bedroom, but as it opened towards my room, I was able to block it effectually with a chest of drawers. The other door opened on to the staircase landing, and as I did not know the inmates of the house I did not relish sleeping with my door unfastened. I therefore tilted one of the chairs under the handle of that door, wedging it in such a manner that no one could open it more than six inches.

This satisfied me, I turned in, and was soon asleep. In my dreams I imagined some one was speaking to me, and gradually they became more and more real, until at last I felt sure some one was actually talking. How long this had been going on I know not, but the first words I can recollect spoken, slowly and deliberately and in a deep funereal strain, were as follows: "You are cursed in mind, in body, and in soul."

I then became convinced I was still dreaming, and that this was a nightmare resulting from my severe seasickness in the morning whilst crossing from Kingston to Holyhead.

The voice continued, "You have dogged my footsteps, but I'll blight your hopes."

By this time I was wide awake, and saw that my door had been pushed open some six inches. A strong ray of light thrown through the opening on the ceiling and wall enabled me to see by my watch that it was 1 a.m.

I could have laughed aloud at this absurd experience; and then, jumping out of bed and going to the door, called out, "Who is there? What do you want?" And then I saw outside my door a tall, grey-haired man, with his candlestick in his left hand, and his right hand raised as he was just finishing his oration.

On hearing my voice he turned on his heel, strode back to his own room (the one next to mine), slammed the door, which I had blockaded on my side, and turned the key with great violence in the lock. I heard him pacing up and down his room, swearing loudly, and then he commenced sawing the legs off a chair.

"Well," I thought, "this is queer. I must go and awaken James, and hear what he says, or knows." And although it was 1 a.m., I went down and knocked at his door. "James," I said "you've a madman in the house."

"No, indeed we haven't—you're dreaming. I've been nine months in these lodgings, and know that the landlady is a widow, and keeps a small ladies' school; and there is not a man on the place."

"Widow or no widow," I replied, "there is a man upstairs, and he's mad!"

With some reluctance he came upstairs, and listened at the bedroom door, and we heard the man still swearing, and still sawing wood. I eventually barricaded my door once more, went to bed, and slept soundly.

At 8 o'clock in the morning the servant brought my hot water, so I asked her who that was next door. She said, "That's master." I told her that he had visited my room in the night, whereupon she replied, "If missus got to know, she would be annoyed."

I asked, "Where is she?"

"She, poor soul," was the reply, "has two days' holiday, and you have her room."

Thus I found out that this brave, self-denying lady had for years endured the brutal treatment of a drunken husband, and had kept his very existence from the knowledge of her lodgers; and by combining the small income derived from her school with that obtained by letting

lodgings, she had maintained her husband and herself.

James told me that my discovery explained the fact of his tea, sugar, cigars, and wine all disappearing; he never would suspect either the landlady or the servants, but now it was all made clear. We hit upon a good plan for detecting the culprit, and I therefore mixed up a strong dose of "tartar emetic" with some wine, and left it in the cupboard, carefully hiding it behind the cruets, pickles, marmalade pot, and suchlike, so that it must be a deliberate act for any one to take it. Next morning it had disappeared, and the thefts did not recur.

About twelve months after this occurrence the landlady was found dead in her bed: she had died of a broken heart.

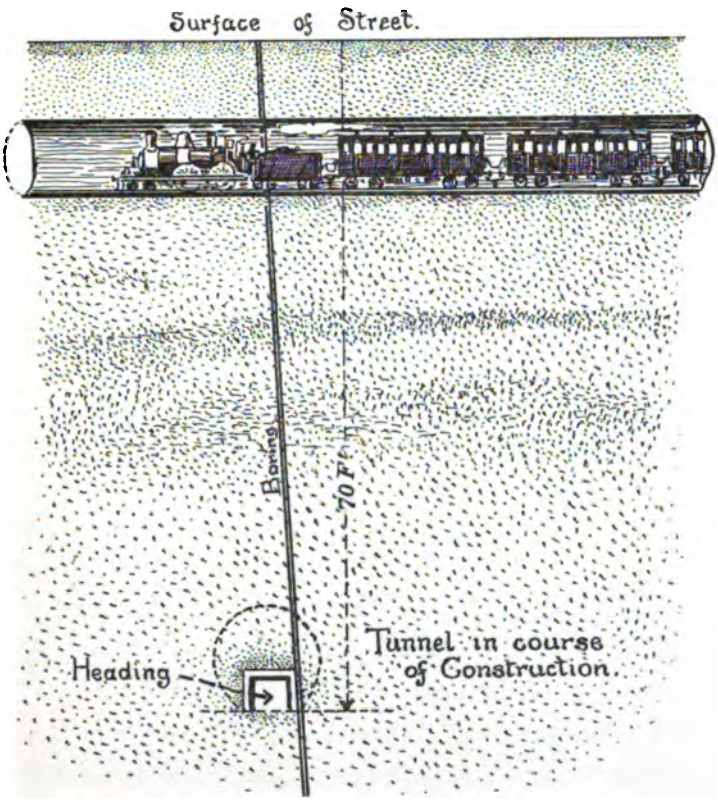
It was in connection with some large works some few years ago that an amusing incident occurred, which is worth recording.

A certain railway company were constructing a tunnel beneath, and nearly at right angles to, an existing tunnel of one of the large English railway companies. As the legal formalities were not actually completed, the engineers were requested to stay proceedings until all was in order,

and they instructed the contractors accordingly; but the latter were anxious not to incur any delay, and they quietly and surreptitiously continued to drive their heading through. The engineer of the existing railway suspected this, and sank a bore-hole on the centre line of the new work, expecting his tool would, at the correct level, drop into the heading at a depth of 70 ft. The contractors looked for a similar result, and therefore placed a sheet of steel on the roof of their drift, so that the tool, when it encountered the steel plate, would simply grind away on the top.

But to the mutual surprise of both the engineer of the existing company and of the contractors of the new work, no drill was encountered, although it had gone to a lower depth than was necessary, some 90 ft. The engineer thereupon lowered, in a foolhardy manner, an explosive charge, and blew in the side of the heading, the tool having meandered several feet to one side. Fortunately no one was hurt, but the engineer was still in ignorance as to what had happened. A bright idea struck him—namely, to lay on the town fire-supply of water down the hole to see if he could fill it. The result was he nearly

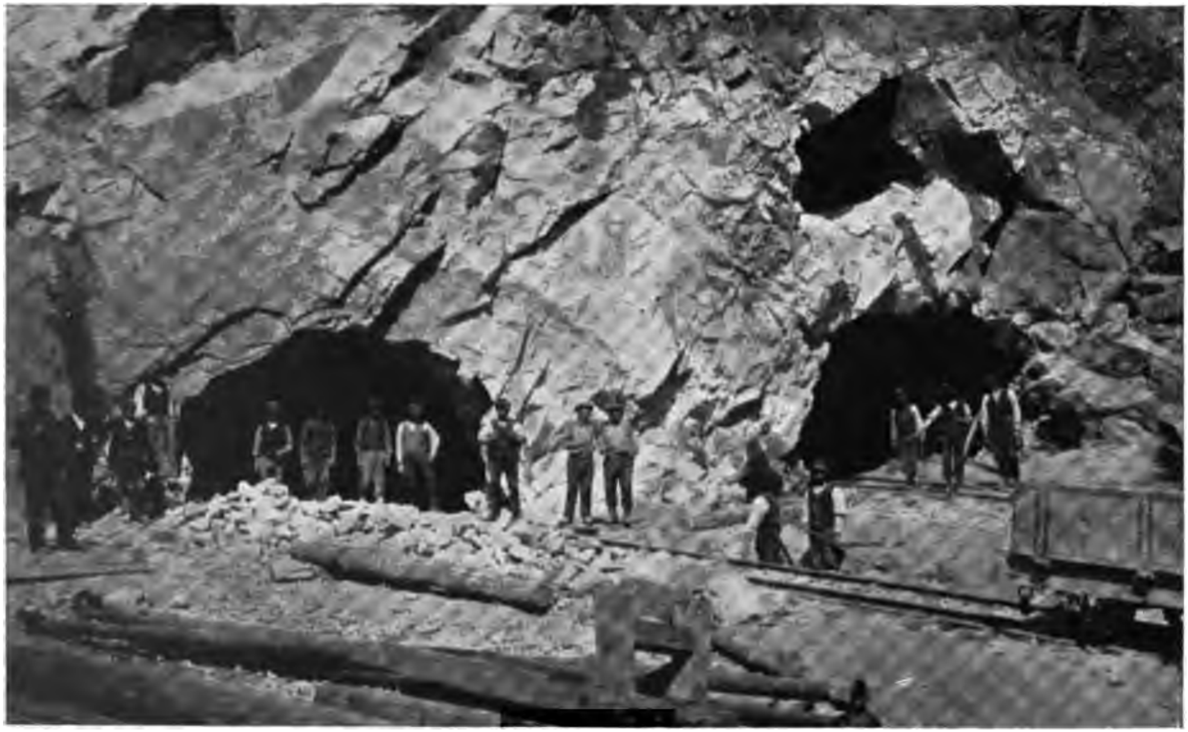
washed the men away in the heading! He thus made his longed-for discovery, but gained nothing,



MEANDERING OF BORING TOOL.

for the legal formalities were concluded shortly afterwards, and the work proceeded.

It was at about this time that another railway company, who had expended £1,000,000 on their works, had the misfortune to incur the loss of some £20,000, in consequence of a large retaining wall being overthrown by the pressure of earth behind. The directors were much annoyed, and the chairman was requested to administer a severe reprimand to the engineer. He was summoned to the next board, and was suitably and severely lectured by the chairman. He then asked if he might be allowed to say a few words. "Oh, certainly." "Well, gentlemen, so far from blame attaching to me, I think the directors are to be congratulated upon the fall of this wall." The directors looked surprised, and could not divine what he meant, whereupon he continued: "Any engineer, however incapable, can make his works sufficiently strong to resist any pressure, but by so doing, and making all the works absolutely beyond question as to stability, the cost would be doubled. It requires a wise and clever man so to design the works as to give the small but necessary margin of safety. The fall of this wall shows I have not thrown money away in any place, and that I have so designed all your works as to be economical. This £20,000



SIMPLON TUNNEL.

Entrances of tunnels, on the Italian side, in the Gorge of the Diveria, near Iselle.

[To face p. 82.

is your only loss; had I made the works unnecessarily strong and absolutely beyond doubt, you would have incurred a total expenditure of another million."

The object of his remark was to prove, if possible, that by greatly reduced expenditure the actual requirements of the work could be attained if a certain amount of risk were run. He, however, had passed the limit of caution, and the result of his reductions had, in this particular instance, ended in partial failure.

The chairman smiled, the board laughed, and the incident closed.

The Great Alpine Tunnels

The question of rapidity in the construction of tunnels is one in which the whole community are more or less, although often unconsciously, interested. If, by the introduction of suitable machinery, the time required for the execution of some great tunnel can be reduced to one-half, or one-third, the loss of interest on the capital involved in the undertaking is correspondingly reduced; and thus great mountain-ranges, which a few years ago were regarded as impenetrable

barriers, or rivers and arms of the sea as impassable boundaries, have been conquered by the engineer.

The Mont Cenis tunnel, having a length of 7·98 miles or 42,135 ft., with a height of mountain above it of 5,428 ft., occupied 13 years in execution; the St. Gothard, whose length is 9·3 miles or 49,104 ft., with 5,598 ft. above it, required 10 years to carry out; and the Arlberg, 6·36 miles or 33,582 ft., with 2,362 ft. of rock over it, have now been eclipsed by the colossal work of the Simplon tunnel. This will be 12·26 miles or 64,725 ft. in length, with a height of mountain above it of 7,005 ft. The work was commenced in August, 1898, and at the end of July, 1903, the distance penetrated amounted to 54,381 ft. in less than 5 years, thus attaining to considerably more than double the speed in the case of the St. Gothard tunnel, and three times that of the Mont Cenis.

When it is borne in mind that, under ordinary tunnelling conditions, the speed falls off as the distance from the portal increases, and that in this particular case very high temperatures of rock and of air and water have been encountered, the above results are remarkable, and speak

SIMPLON TUNNEL, BRIGUE ENTRANCE.

The ventilating arrangements and the timber roof over railway to protect men from exposure when emerging from tunnel.

[*To face p.* 84.

volumes for the skill, determination, and the unconquerable perseverance of those engaged in the work.

This great undertaking will consist of two single-line tunnels, running parallel one to the other, at a distance apart from centre to centre of 55 ft. 9 in. ; and one of the chief features is the much lower altitude of the rails above sea level than any of the other Alpine tunnels. This altitude is at its highest point 2,314 ft., being 1,474 ft. lower level than that of the St. Gothard, 1,934 ft. lower than that of the Mont Cenis, and 1,986 ft. lower than that of the Arlberg. This is a matter of great importance in the question of haulage of all the traffic.

The tunnel enters the mountain at the present level of the railway at Brigue, so that no costly approaches are requisite on this side; but, on the Iselle side, the connecting line with the existing railway at Domo d'Ossola necessitates heavy work with one helical tunnel. The gradient on the northern portion of the tunnel will only be that sufficient for drainage, viz. 1 in 500, but on the southern portion the gradient will be 7 per 1,000, or 1 in 142.

Admirable arrangements have been made for the

welfare of the men, to avoid the heavy death-rate which occurred on the St. Gothard, and it may be interesting to state what some of these are. For every cubic foot of air sent into the latter tunnel, fifty times as much is delivered into the Simplon. Special arrangements are made for cooling the air by means of fine jets of water and spray. The men on emerging from their work, wet through and fatigued, are not allowed to go from the warm headings into the cold Alpine air outside, but pass into a large building, which is suitably warmed, and where they change their mining clothes and are provided with hot and cold douche baths. They put on warm, dry clothes, and can obtain excellent food at a moderate cost before returning to their homes. Their wet and dirty mining clothes are taken charge of by appointed custodians, who dry and clean them ready for the morrow's work. These and other precautions have reduced the death-rate to a very great extent.

With a view to the rapid advancement of the work, the late M. Brandt, whose death is greatly to be deplored, devised, after his long experience on the St. Gothard, his now well-known drill. It is a rotatory and non-percussive drill, 3 in. in diameter, with a pressure on the cutting points of

SIMPLON TUNNEL.

The douche baths for the workmen, and the arrangements for drying their wet clothes on returning from the tunnel.

[*To face p.* 86.

10 tons, moving at slow speed, but capable of being accelerated at pleasure, and of being rapidly withdrawn. It is armed with a steel tool with 3 cutters, and the carriage on which it is mounted enables it to work in any direction. The face of the tunnel is attacked by 10 to 12 holes in the case of the hardest rock, those in the centre being 3 ft. 3 in. in depth, whilst those round the circumference are 4 ft. 7 in. The drills are driven by hydraulic pressure of 100 atmospheres or 1,470 lb. to the inch, and the cutter having a $\frac{3}{4}$-in. hole along its centre, all the waste water is discharged right on to the cutting edges, thus keeping them cool and washing out the débris.

The time taken for each portion of the attack in the hard Antigorio gneiss is as follows :—

Bringing up and adjustment of drills .	20 minutes
Drilling	$1\frac{3}{4}$ to $2\frac{1}{2}$ hours
Charging and firing	15 minutes
Clearing away débris	2 hours ;

or a total of between $4\frac{1}{2}$ to $5\frac{1}{2}$ hours, resulting in an advance of 3 ft. 9 in., or a daily advance of nearly 19 ft. 6 in., the size of the heading or gallery being 10 ft. in width and 6 ft. in height, the area being 60 square ft.

From October 1st, 1902, to June 30th, 1903, the

progress made at the two "faces" was as follows: Total advance from Brigue, 5,050 feet (1,539 metres); from Iselle, 4,610 feet (1,405 metres); or 18·4 feet (5·6 metres) per working day. If allowance were made in the above calculation for delays caused by Saints' days, timbering, lengthening mains, etc., the daily average would be still larger; but a progress of over 18 ft. a day, through hard rock, hindered by high temperature, heavy feeders of water, great distance from the portals, and other causes, over a period of 9 months, is record progress.

Notwithstanding the great distance from the open air that the advance headings have now reached, namely, a total of nearly 12 miles, and the very high temperatures encountered, not a single case of phthisis has ever occurred on the tunnel, and the health of the men throughout is of the highest standard: this being due to the care displayed by the officials and contractors, and also to the absence of dry drilling in the advanced headings.

It was expected that, in consequence of the mountain *massif* existing over the tunnel, a high temperature would be encountered; but this has been considerably exceeded, and it is the opinion of some well able to speak with authority that

SIMPLON TUNNEL.

The Brandt hydraulic rock drill entering tunnel with its gang of workmen, showing the rack bar holding three separate boring machines.

[*To face p.* 88.

THE STEEL CUTTER OF THE BRANDT HYDRAULIC DRILL.

Three inches in diameter; the waste water is discharged along the axis of the drill, up to the cutting edges.

[*To face p.* 88.

connection exists between these and the great eruptions in Martinique and St. Vincent. At the time of these catastrophes certain cold mineral springs, at Teplitz, in Austria, for example, began to run hot water. When, however, the great height of the mountain above the tunnel (7,005 ft.) is considered, this being the greatest depth at which man has ever been below ground, one is driven to the conclusion that the high temperature is due to this.

The maximum heat, which has been recorded in the advance headings from Brigue, is no less than 55° Cent. (131° Fahr.), whereas on the southern or Iselle side the great spring which was met with at 2¾ miles (4,400 metres) from the portal has no doubt acted as a refrigerator, the maximum heat attained being 37·5° Cent. (99° Fahr.).

The introduction of machinery does not always result in increased speed; of this a notable instance occurred in a certain tunnel with which the author was connected. A heading through rock had to be driven, the distance between the portals being 6,000 feet. At one end hand-labour was employed, and effected a steady advance of 27 ft. per week. At the other end machinery was used, and so well did it do its work that occasionally as much as

201 ft. a week were penetrated. Then a break-down would occur, resulting in a long stoppage; at last, when the two "faces" finally met, it was found that the advance made by the machine was exactly at the same average speed as by hand-labour—27 ft. per week.

In a recently constructed main-line tunnel, with which the writer was connected, the length being 9,000 ft., the average advance at each "face," including those from the portals and from numerous shafts and break-ups, was 1 ft. 6 in. per day per "face" of excavated and brick-arched tunnel.

The method of checking the alignment of the Simplon tunnel is of too technical a character to be more than briefly referred to. On certain days the works are stopped for the purpose. Instead of employing wires, a slit of bright light is used, the points outside the tunnel being fixed by triangulation, and the survey tied in from the summits of Monte Leone, the Wasenhorn, and the Faulhorn. Such is the accuracy attained in this survey that the error in the meeting of the two headings will probably be only a few inches in a length of 12¼ miles, and we await with much interest the meeting of the galleries, when the actual divergence can be measured.

SIMPLON TUNNEL.
Two and three-quarter miles from the Italian portal, showing the "Great Spring" encountered in the advance heading.

SIMPLON TUNNEL.
Six miles from entrance, showing timbering during construction.

[To face p. 90.

The alignment is not only fixed by the company's engineers, but it is again checked three times a year by experts from the Government Survey Department at Lausanne.

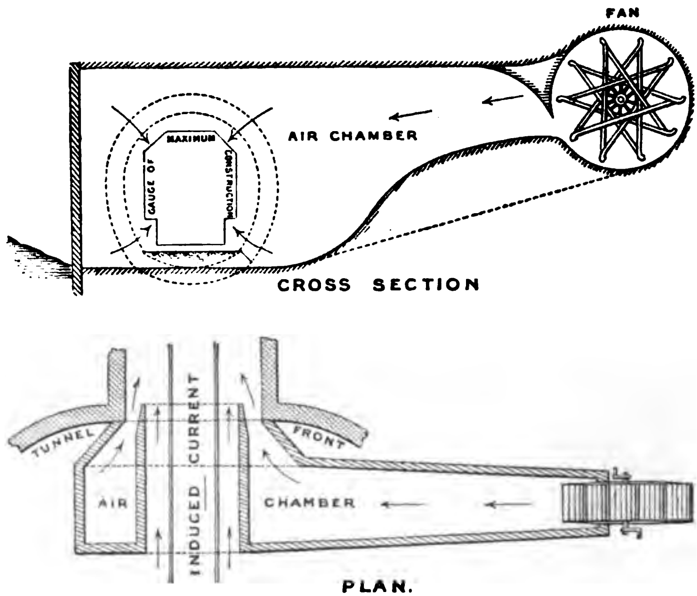
It is desirable to point out how very necessary it may be, in the case of this and other long tunnels, that electric traction should be adopted. Abundant power close at hand already exists; the air of the tunnel would not be vitiated—a matter of great importance where briquet fuel is used—and the rapidity of conducting the traffic would be improved.

In 1894 I carried out some interesting experiments at the Pracchia Tunnel, on the railway through the Apennines between Florence and Bologna.

The excellent system of ventilation which has been introduced by Signor Saccardo,* the engineer-in-chief of the Italian railways, can with advantage be mentioned. The railway consists of a single line, and was built many years ago by the late Mr. Brassey. There are 52 tunnels in all, but those on the eastern side are of comparatively little importance. On the western slope the gradient nearly throughout is 25 per thousand (or 1 in 40), and it is here the greatest difficulty exists. There

* It is much to be regretted that since this paragraph was written Signor Saccardo has died. April, 1904.

are several tunnels, whose lengths approximate to 1,000, 2,000, and 3,000 yds., and the traffic is both heavy and frequent, the locomotives very powerful, with eight wheels coupled.



SACCARDO SYSTEM FOR VENTILATING TUNNELS.

Under any conditions of wind the state of the longest tunnel is bad, but when the wind is blowing in at the lower end at the same time that a heavy goods or passenger train is ascending the gradient, a state of affairs is produced which

SIMPLON TUNNEL.

Locomotive used inside the tunnel, provided with large boiler to avoid firing up whilst under the mountain.

[*To face p.* 92.

is almost insupportable, and one might as conveniently travel in a furnace flue.

A heavy train of dining- and sleeping-carriages, with two engines, conveying one of the crowned heads of Europe and suite, arrived at the exit of Pracchia Tunnel with both engine-men and both firemen insensible: and in other cases passengers have been seriously affected.

Owing to the height of the mountain no shafts are available; but Signor Saccardo places a ventilating fan near the mouth of the tunnel, and blows air into it through the annular space which exists between the arch of the tunnel and the gauge of maximum construction (see diagram on opposite page). The results are remarkable; the volumes of air thrown into the tunnel per minute being as follows:—

	cub. ft.
Direct from the fan	161,860
Induced draught through open tunnel mouth .	48,140
Total	210,000

Or 100 cubic metres per second.

The temperature of the tunnel air before the fan was started was 107° Fahr., with 97 per cent. of moisture, whereas, after the fan had been running

a few minutes the temperature was 81° Fahr., or a lowering of 26° Fahr., and the tunnel was cool and free from smoke and vapour.

One can travel through with both windows open and feel no inconvenience, the only remark of the brakesman riding on the top of the waggons and carriages being that he finds it almost too cold.

This application is without doubt the solution of the difficult problem of tunnel ventilation under high mountains, and elsewhere where shafts are not available, and where electric traction is not applicable.

This system has been brought into operation on the St. Gothard, with the most satisfactory results. Careful experiments are being made, but there is no doubt that the problem has been solved.

In addition to these tunnels, the Saccardo system has been applied to the Giovi Tunnel near Genoa—3,300 metres in length—to the Giovi Tunnel on the Genoa-Ronco Railway, 8,303 metres in length, besides to some seven other tunnels in Italy; also to the tunnel of l'Albespeyre in France, the Cochem Tunnel in Germany, and the Elkhorn Tunnel in America.

In constructing the Great Central Railway into London, the line passes in three tunnels with

From "Engineering."]

SIMPLON TUNNEL.
Building the granite arching of tunnel.

[To face p. 94.

SIMPLON TUNNEL.

Miners about to enter the tunnel at Brigue, in the Rhone Valley. The method of transporting the small hand tunnel-waggons upon larger trucks is shown.

[*To face p.* 94.

seven pairs of rails under Lord's Cricket Ground. By the Act the company had to acquire the Clergy Orphanage which was near the Ground, demolish the buildings, construct the tunnels under the land, cover it all up, turf it, and hand it over to "Lord's" before entering on their property in any way. This was impracticable, for we required "Lord's" to enable us to tip the material from the Orphanage; and to save loss of time we went to see the late secretary of the M.C.C. to obtain permission to drive the preliminary driftway right through, so that the works beyond could be proceeded with. Had not this been conceded, one and a half to two years' extra time would have been required to open the railway.

He said, "Go and do it—but don't let me know anything officially about it."

We at once proceeded with it, and all went well until the Harrow and Eton match about a year later. The contractors had opened up a small shaft, 3 ft. square, to admit air to the workmen; and although on the occasion of the match this was covered and turfed temporarily, yet unfortunately one of the luncheon tents had been pitched over the spot.

During lunch some ladies noticed a curious

smell, and one of them said, "Do you see, there's smoke coming up through the grass?" This unusual phenomenon became the subject of conversation, and shortly after we received a letter from the club to this effect: "It has come to our knowledge that your company has, in direct contravention of the Act, entered on the property of 'Lord's' and has driven a heading under their ground."

We did not at first reply to it; but receiving a second letter pressing for an answer, I took it to the late secretary.

He said, "You reply simply, 'Nothing has been done but with full knowledge of your secretary; you had better confer with him.'"

We heard no more about it.

The construction of "Tube Railways" under London has been so often, and so fully described in the engineering papers that it need not be referred to at any length here. The Greathead shield, driven through the solid London clay, alone renders such work possible; and such is the accuracy attained that cases occur in which two shields, started 1,300 to 1,400 yds. apart, and driven towards each other, have met edge to edge, and they have been left in to form a portion of the iron lining of the tunnel. In December, 1903, two shields

SIMPLON TUNNEL.

Crossing of the Rhone by the steel hydraulic main (3 ft. 3 in. diameter) conducting water from the water-house to power-house, a distance of about two miles (250 lb. pressure per square inch).

[*To face p. 96.*

on the Hampstead "Tube" under Haverstock Hill met, with the following small inaccuracies:—

Error in direction . .	One quarter of an inch.
Error in level . . .	One-eighth of an inch.
Error in length (which was over 4,000 ft.) . .	Seven-eighths of an inch.

The adoption of passenger lifts at the stations necessitates the testing of every one of them by the Board of Trade. One or two are tested by loads of pig-iron, and they are allowed to fall, the object being to make sure that the automatic catches will come into operation in case of need. In all cases this fall has never exceeded more than a few inches; and as the ropes are provided with a strength of twenty times their maximum load, no anxiety need be felt by those who use the lifts.

The remainder of the lifts are tested by a living load of eighty workmen, including the Government inspector, the engineers, and contractors, who thus show their fullest confidence in the safety of the apparatus.

CHAPTER VI

INCIDENTS CONNECTED WITH RAILWAY CONSTRUCTION

On a certain railway in the North of England a curious result was observed during construction in one of the cuttings. A powerful "steam-navvy" or steam excavator was at work, removing some 12,000 to 15,000 cubic yds. of earth each month; but in consequence of a heavy gale of wind blowing the sea-sand from the shore into the cutting, there was actually more material in the excavation at the end of the month than there was at the beginning.

At a depth of 15 to 20 ft. we came across the remains of garden walls, and even of turf of a lawn which, in years gone by, had been overwhelmed and buried by the continually advancing sand. This is identically the same result which one sees in Algeria, where the drifting sands of the Sahara have buried Roman cities—the

aqueducts, archways, and various buildings, with innumerable columns, standing to this day half hidden by sand. The buried cities of Khotan constitute another example of the same phenomena.

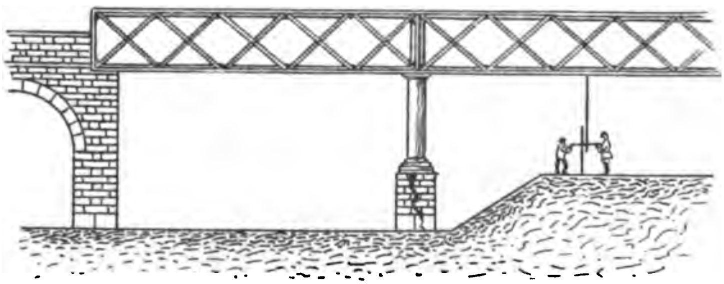
When a railway is completed and ready for traffic, the Board of Trade send their inspecting officers to ascertain if every portion is satisfactorily constructed, and of ample strength.

The testing of bridges is effected by loading the entire length of the girders on both lines with the heaviest locomotives. The engines then run over the bridges at high speed, and are also brought to a condition of rest over the span.

To casual observers this seems a very severe and unnecessary test; but they would be more surprised were they informed that, in order to cause the bridge to collapse, it would be necessary not only to cover the whole surface with these heaviest of locomotives, but they would have to be also piled up on the top of one another in rows of four or five deep.

The testing is generally a very simple matter, and is carried out by means of two wooden rods, one of which is suspended from the underside of

the girder, hanging down vertically, the other standing on the ground and placed side by side with the former. A line having been drawn across both rods before any load is on the bridge, the locomotives roll on, and whatever deflection they cause in the girder is indicated by the distance between the marks on the rods caused



METHOD OF MEASURING DEFLECTION OF BRIDGE.

by one sliding on the other. If this distance be within the calculated amount, the bridge is safe.

On one occasion, some years ago, a large lattice girder bridge carrying a certain main line into London was being tested, and I was holding the rods and measuring the deflection. There were three lines of way on the bridge, with three locomotives on each line, or nine in all.

At a given signal they ran on, and we ascertained the deflection; they then were taken off the bridge in order to measure the amount of "permanent set" which remained in the ironwork, and this was duly recorded. To my surprise I found that the brick pier, on the left-hand side of the above rough sketch, was cracked from top to bottom, not merely on one side, but on all four. I shouted to the official in charge of the engines, "Don't let them come on again"; but with so much noise, accompanied by whistling and blowing off of steam, he evidently only heard the last words, "let them come on again," and on they came! I could not desert my post, but kept one eye on the rods and the other on the girders, in case anything should happen; and I noticed the cracks gape wider and wider, until they were two inches broad at the top.

The engines were removed as quickly as possible, and the pier had to be rebuilt, when it was found that the cause of the injury was due to the masons having improperly fixed the bed-stones under the column, which thus acted as powerful levers, cracking the pier, which was ten feet square, into four parts. The remaining three piers were

made secure by forcing liquid cement under pressure into all the crevices.

A laughable incident occurred recently at the Government inspection of an important railway. Eight locomotives were being used, four on each line, for testing the bridges. The Traffic Superintendent entered one of the signal-boxes, and rang up on the telephone the signalman at the next station, when the following conversation took place :—

"Are you Brackton signal-box ?"

"Yes."

"Well, look here : the Government Inspector is coming, with four locomotives on each road ; so you must block all traffic, as four of the engines will be travelling in the wrong direction."

The signalman replied, "I shan't let them pass : it's contrary to regulation."

"But you must."

"But I won't."

"You *must* : he has control of the line, and can do as he likes."

To which the signalman replied, "Oh ! I say, this is a sort of a mixed-up job ; who are you ?"

"Never mind who I am—you do as you're told."

Signalman: "I say, did you get any rabbits last night?"

"Rabbits? No, of course I did not."

"Didn't you? I got fourteen."

The man had been out poaching during the night, to celebrate his coming out of a smoky city into the country. It is unnecessary to add that the Superintendent of the Line good-naturedly took no notice of the incident.

Whilst constructing the Great Central Railway, I was at Canons Ashby, near Byfield, Northants, staying with the late Sir Henry Dryden and Lady Dryden. An amusing episode had occurred just before my arrival. Sir Henry was dressed like his ploughman, in corduroy and gaiters, and a low-crowned cap with flat projecting peak. He was in the roadway near his house, and met a drover with some cattle. The drover said to him, "Oi say, d'ye think oi can get a drink at that house?" pointing to Canons Ashby.

Sir Henry said, "I daresay you can; go and try."

The man asked him to mind his cattle, and went. On his return Sir Henry said to him, "Well, did you get a drink?"

"Oh yes, they treated me fine; and there's threepence for your trouble."

Sir Henry took it, and was going on, when a gentleman on horseback, passing by, shouted out, "Good-morning, Sir Henry."

The drover on hearing this went to him and said, "Why, surely you bean't the Squire, be you?"

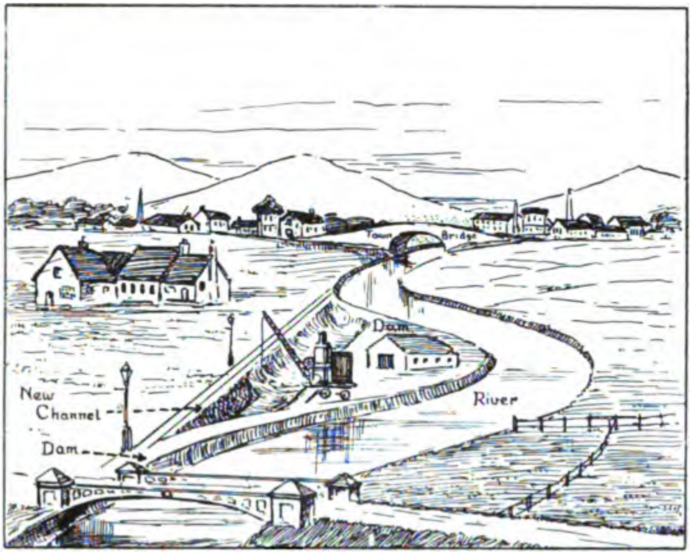
"Well, perhaps I am."

Whereupon the drover said, "Then give me back my threepence."

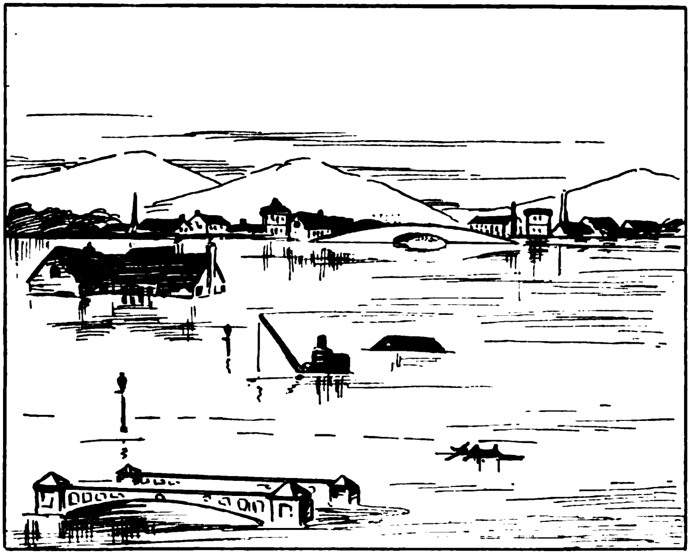
Sir Henry replied, "Not a bit of it; it's the first threepence I have ever earned in my life in this way."

In 1887 I was one day telegraphed for, to go over a railway in course of construction, as the whole of the works and an intended diversion of the river were under water.

It had rained continuously for three or four days and nights, and, amongst other accidents, the Manchester Ship Canal works had all been drowned out, and the River Mersey in places had broken into the canal. We were diverting a river and making a new channel. A temporary dam had been left at both ends, and the men were busy putting in the walls in trenches. But in doing so we came unexpectedly on a bed of coal, of which no records exist, only 11 ft. from the



Before the flood.



Twelve hours later.

DIVERSION OF A RIVER, SHOWING THE NEW CHANNEL IN COURSE OF CONSTRUCTION.

surface, and which had been worked some century or more ago by the "pillar-and-stall" system, by which alternate blocks of coal twenty or thirty feet square are left between the passages and working places. The result was that where we encountered a "pillar" we built on the top of the coal, and when a "stall" was found we had to concrete down to the bottom of the seam.

The work was going on well until the flood came, and the river, being held back by the town bridge, rose in height, topped the lower dam, filled the trench, "took charge," and, sweeping both the dams away, rushed unimpeded along the partially finished channel. The two rough sketches give some idea of the condition of affairs.

The flooding of the works would not have mattered so much, had it not been that the water got into the seam of coal and, following it down to the "dip," began to flood some of the collieries in the neighbourhood, 800 yds. in depth, and some two or three miles away. To get a river out of a coal mine 11 ft. deep is difficult enough, but to get it out from a depth of 800 yds. is a very different task.

I could only sit on the parapet and watch the flood, as we were for the time helpless. We had

to wait until the water went down, when we were able to restore the dam and pump out the trench; but no sooner was this done than another flood came down and repeated the same experience. By dint of great energy on the part of the contractor, the foundations were concreted up, and the work finished, and now no trace of this trouble remains.

It has always been our resolve, in connection with engineering works, to have no labour employed on Sunday, if it could in any way be avoided; of course, in cases of emergency or danger it would be necessary, but, as far as possible, nothing else justifies it.

We once carried out an important tunnel, two miles in length, the contract being executed by a well-known firm, and it was completed in a record short time. When finished, the contractor said to me: "This absence of Sunday work has saved considerable time; we have just finished another important tunnel elsewhere, in which not only was Sunday work allowed, but it was ordered by the company, and we found that both loss of time and unnecessary expense resulted. The men came back worn out on Monday, instead of being refreshed by a Sunday's rest; the boys, the horses, the very engines and boilers, need their Sunday."

Sunday is known as the Lord's Day, and it is the duty of all to observe it as such, in memory of our Lord, and not to devote it to travelling or pleasure, which generally entails labour on the part of others for our convenience, and which robs them of opportunities for worship and rest. Let us make the day as bright and cheery as possible, using it for mental and spiritual growth, for acts of kindness and mercy, and for the relief of sickness and distress. Sir Matthew Hale's verses are still very much to the point:

> A Sunday well spent brings a week of content,
>   And strength for the toils of the morrow;
> But a Sabbath profaned, whate'er may be gained,
>   Is a certain forerunner of sorrow.

France and some other Continental countries have to a great extent lost their Sundays, and are now endeavouring to regain them: let us not as Britishers do anything to break them down.

CHAPTER VII

MINING INCIDENTS

It was my good fortune, after studying at the Government School of Mines, to spend some years of my life in mining, eventually becoming mine manager; and this experience has proved of great service in connection with such matters as tunnelling and ventilation. In various parts of the world I visited mines of almost every description, from coal and ironstone to diamond, gold, and silver, as well as oil and gas wells, almost the only description of mine that I have not seen being quicksilver.

About 1876 a merchant in London came to ask us to design, order, and ship out to the Andes, in Chili, some complete mining plant for a silver mine. He brought us the order and specification in Spanish, but we pointed out to him that we should not like to undertake the responsibility of translation. This he considered reasonable, and in the course of a few days he returned with it in English.

We set to work, designed and ordered a very complete plant. The mine was high up in the Andes, so that every part had to be taken up by mules; consequently engines, boilers, and every subsidiary part had to be so designed that no piece should exceed 400 lb. in weight.

The shaft was 10° from the vertical, so the cage had to run on inclined rails. There were winding engines for the shaft, hauling engines for the underground planes, pumping engines, boilers, girders, pulleys, ropes, waggons, and also the necessary buildings. All had to be perfectly complete to the last screw. We had it all put together at the makers' works, all tried in steam and tested, then carefully packed, shipped, paid for, and our work was done.

From the time the order left the mines to the time when the long cavalcade of mules were toiling up the mountains, some two years had elapsed. We heard nothing more about it until three years afterwards, when by chance I met the merchant in Cannon Street, and I asked him how the machinery had answered.

He said, "What! haven't you heard?"

"No, not a word."

"Didn't you hear of the mistake?"

"No; what mistake?"

"Don't you recollect you declined to be responsible for the translation? Well, the man who translated it made a mistake in the translation from Spanish to English measurements, and forgot to divide by two. The result was the cage was twice as long and twice as wide as it ought to have been, and it wouldn't go into the shaft; and everything was in the like proportion. We couldn't use it, and sold the whole thing, lock, stock, and barrel, to an adjacent mine, and began again."

This points to the necessity of extreme accuracy, especially in connection with foreign orders. Had the metric system been in use in England, the error would not have occurred. Great Britain is losing a large amount of foreign trade owing to our adhering to the very inconvenient system of English weights and measures.

When mining in Yorkshire in 1874, having to design and erect for our workmen some hundred or more cottages, I determined to make them roomy and comfortable, and therefore consulted the men who would have to live in them as to various arrangements.

I got several good ideas, and at once incorporated them into the design. Not being, however

satisfied altogether, I decided to confer with one or two of the wives of our leading men, as to the position of the kitchens and the arrangement of bedrooms, they being the people chiefly concerned in the household.

One woman, to whom I explained the plan as well as I could, replied, "I think they will make very good houses; but you have forgotten one thing."

"Have I? What is it?"

"You can't get a coffin out of the bedroom, owing to the sharp turn on the staircase; it will have to be taken out of the window."

"Good gracious! Whatever made you think of such a thing?"

And she replied that she had been living in a village of five hundred houses in Durham, and every one of them suffered from this inconvenience.

This impressed me greatly, and ever since then, whenever I have had to design anything—buildings, engines, pumps—I always consult the actual men who have to work them.

About the year 1875 I was asked by the Cleveland Mine Owners' Association to allow Lord Iddesleigh (then Sir Stafford Northcote),

Chancellor of the Exchequer, and other members of Parliament, to visit the mines. These mines are 170 yds. in depth, the seam being 9 ft. in thickness, and the ventilation is by a 30-ft. Guibal fan.

I was asked on Tuesday, the market-day, and the Chancellor of the Exchequer was to visit the mines next day at noon. I at once telegraphed to the mines for the officials to make the necessary arrangements, and also to the hotel to send luncheon for twenty-seven persons, with a sufficient number of waiters.

All worked late and early, and on my arrival at the mines I found everything ready. The party consisted of the Chancellor of the Exchequer, Sir Isaac Lothian Bell, Sir J. Whitwell Pease, and six other members of Parliament; also several of the leading ironmasters of Middlesbrough—about twenty in all.

It was arranged for the luncheon to be given, not in the engine-room at "bank," but in one of the working-places of the mine. The waiters, however, refused to go below, and had to be "run in" to the cage, and taken down the shaft, when they found it not so terrible as they expected.

The ventilating fan was stopped to prevent a current of air, as half a mile of the workings had been lighted with candles. The whole process of getting the ironstone, the drilling, blasting, and breaking up, was explained; and then, from the deep gloom of the mine, the party were ushered into a little bit of fairyland. A working-place had been draped all over with white calico; chandeliers with wax candles and candelabra brilliantly illuminated the place; tables were sumptuously furnished and spread, and with flowers and glass looked really charming. Sir Stafford told me that it was one of the most impressive sights he had ever seen, and all went away delighted.

The officials, the foremen, the deputies, the miners, and the boys came in, in rotation, to finish the luncheon, which, having been ordered for twenty-seven persons, actually sufficed for a hundred and sixty.

In 1876, in consequence of overwork, I had to take a month's holiday in Italy; and during my absence I heard that there had been a drunken fight in the dark amongst the miners, that a man had been seriously injured, and that a miner named George Field had been sent to

hard labour for eighteen months, on account of it.

I was much distressed on hearing this, as I had endeavoured to check intemperance among the men, and had refused to allow a public-house to be erected, had instituted reading and recreation rooms, and established lectures, cricket and football clubs, and other civilising influences. But they had obtained drink at an adjacent village, and came back to our place much the worse for it. However, Field had gone to gaol, and nothing more could be done.

Six months later, when I was on the bench with the late Canon Yeoman, the Inspector of Police informed us that there was a man in court who wished to make a statement to the bench.

I told the inspector to ask the man to step up into the witness-box, when a miner named Hand appeared. On asking him what he wished to say, he replied, "Field didn't strike the blow."

I said to him, "What! *Do* you mean to say Field is innocent?"

"Yes."

"Then who did strike the blow?"

"I did."

We committed him for trial to York Assizes, and he received four months' hard labour. Meanwhile, we had applied to the Home Secretary to release Field; but he said he could not do so until Hand had been tried, and, if convicted, he would then recommend Her Majesty to pardon Field.

After an interval of seven months Field was released, and I was the first person, after his wife, that he called upon. I met him at my front door, shook hands with him, and asked him in. I told him how very sorry I was that he had undergone such a long imprisonment for an offence which he had not committed, and he replied: "You need not be unhappy on that account, sir—it is the best thing that ever happened to me. Before I went to gaol I was a drunken, dissolute fellow, always quarrelling with my wife, and consequently had a wretched home. From now, all this will be altered."

I asked him what had produced this result.

"When in gaol," he said, "the chaplain or the governor came into my cell and was locked in with me. He helped me to pick my oakum, or make my mats, and showed me how to use

the knife and needle; and at the same time begged me to turn over a new leaf, and I've done it."

When the order came for his release, as he was going down the corridor of Northallerton Gaol, he happened to meet Hand coming in to serve his time. He said to him, "Hand, whatever induced you to give yourself up like this?" and his reply was, "I couldna bear it no longer. I didn't ought t'let you went." Hardly a good specimen of Anglo-Saxon, but a proof of the genuineness of the man. The governor and chaplain have doubtless benefited many a prisoner by their kind and sympathetic influence.

In June, 1899, I was in America, and Field, who had been out there some years, came to see me in New York. He had never recovered from the effects of the prison plank bed, the severity of the discipline having permanently weakened his lungs. I saw the officials of the Home Office on my return to England, and with some difficulty persuaded them to help him. They kindly gave me £20 to expend for his benefit, which I did, with excellent results, purchasing clothing, tools, and food; and he is still endeavouring to earn his livelihood in the States.

In order to interest the miners and to keep them from the public-houses, I organised, as already stated, cricket and football clubs, also a horticultural society, with prizes for the best gardens; and arrangements were made for lectures to be given once a fortnight during the winter months. In connection with these I was asked by a large colliery owner to give a lecture to his colliers in an outlying village near Coxhoe, in Durham, and of course did not refuse, as natural sympathy with our toilers underground has always made me desirous of brightening their lives as far as possible.

It was a dark winter's night, and the village was far away on the lonely moors; but when I arrived at the schoolroom I found it densely packed with miners, their wives and children—some five hundred in number. I gave them an optical lantern entertainment, introducing various experiences, interspersed with anecdotes; then there were a few humorous, but refined pictures exhibited; and finally, to finish up, I threw, by means of a bisulphide of carbon prism, a lovely spectrum upon the sheet, and explained the white ray of light as being composed of the three primary colours, red, yellow, and blue, and how by suitable means they could be brought

together again to form the original ray of white light—three in one, and one in three. The functions of these three colours were briefly and popularly described, the red being the heating ray, the yellow the lighting ray, whilst the blue is the chemical and actinic ray, by which photography is chiefly done, and which contributes very largely to the growth of plants. I then explained to them how it was necessary, in order to produce really healthy vegetable life (as many of these miners are gardeners), that these rays should be combined in white light. I asked them, "Supposing you grew your seedling lettuces or cabbages in a frame provided with red glass, thus giving them only the heating ray, or with blue glass, only giving them the actinic ray, what would happen?"

"They would damp off."

"Yes, exactly; and in order to get healthy life you must have the combination of all three, and this is the most perfect illustration in nature of the doctrine of the Trinity. Although we cannot understand how Three can be in One, and One in Three, any more than we can understand it with light, we must accept it if we desire to have real and true spiritual life."

Next day two of these kind-hearted, black-faced

colliers, just coming out of the pits, helped me to carry my things down to the railway station, and we chatted as we went. I asked them which portion of the lecture they preferred, thinking probably they would have mentioned the more humorous part; but to my surprise they said, "Them three colours." On asking the reason, they said that, a fortnight before, a lecture had been given by "Iconoclast," the subject being "The doctrine of the Trinity a mathematical absurdity," and that it had "fetched a lot of us fellows"—in other words that it had more or less carried conviction to their minds—"but them three colours didn't fit in with his argument," for they now saw that it was possible for Three in One, and One in Three, to be absolutely true.

Surely it could be nothing less than providential that this subject should have been referred to without the lecturer even being aware that any one had, only a fortnight previously, spoken and raised doubt on this very question.

Again, in connection with these lectures, my friend Archibald H. Irvine brought to my house in August, 1877, two of the first telephones ever used in England. He had made them from a description which had been cabled from America,

so soon as the invention was completed there, and he laid a wire from one end of the house to the other, and we were able to speak from room to room.

One remarkable effect produced was this. As the rooms were not far apart, we could by speaking loudly hear one another's voices without the use of the telephone. When we used the telephone, the words reproduced by the instrument were of course practically instantaneous to the receiver, whereas the words which had to travel through the air had to follow the laws of sound, and consequently lagged behind. In other words, we were perfectly well able to appreciate the loss in time by transmission through the air, even over such a short distance.

We also tried for the first time speaking along the telegraph wires on the North-Eastern Railway—some seventeen miles—from Huntcliff Mines, belonging to Messrs. Bell Brothers, near Brotton, to Middlesbrough; and the iron merchants came to hear, for the first time, this wonderful instrument.

The following article in a Middlesbrough paper of September 29th, 1877, is of historical interest, it being an account of the first application in

England of the telephone to any long length of wire:—

"On Wednesday an opportunity was afforded to a considerable number of gentlemen of witnessing the operations of the telephone at Messrs. Bell Brothers' offices, at Middlesbrough. Mr. Irvine, a gentleman of considerable scientific ability, who has devoted himself to the art of telegraphy, on observing the accounts of Professor Graham Bell's invention, set to work to construct a similar instrument, and during his recent stay with Mr. Francis Fox, at Saltburn-by-the-sea, has made a number of experiments over a short distance of wire, viz. between the houses of Mr. Fox and Mr. W. S. Ayrton. Desiring, however, to try his apparatus over a greater length of wire, Mr. Fox asked Messrs. Bell Brothers (Limited) to put one of their wires at the disposal of Mr. Irvine; and accordingly on Tuesday arrangements were made for disconnecting the intervening instruments, making a through wire from Middlesbrough to the Huntcliff Mines—a distance, as our readers will know, of more than seventeen miles. Unfortunately, through the misapprehension of one of the clerks, the circuit could not be completed on Tuesday, but on Wednesday the experiment was

repeated, and with very satisfactory results. Messrs. Bell Brothers' wire passes on the railway company's poles from Middlesbrough to Huntcliff, and on the same poles are hung a considerable number of wires used for the company's own service. These materially interfered with the perfectness of the operation, as the powerful currents employed in ordinary telegraphy set up what are called "induced" currents in the wire which was being devoted to the telephone; and though usually these "induced" currents do not impede in any way telegraphic communication, yet with so delicate an instrument as the telephone they are a serious hindrance, the least electrical disturbance interfering with it. The telephone, we may say, consists of a straight magnet, something under five inches in length. In front of one of the poles of this is fixed a plate of iron about the thickness of a sheet of note-paper. Round the magnet is wound a fine copper wire closely wrapped with silk, and to the ends of this wire are attached the wire of communication. An operator speaking into the mouthpiece of this instrument, and against the thin plate of iron, causes it to vibrate in harmony with his voice, or any other sound which he may produce, and

the plate approaching and receding from the magnet, an increasing and diminishing amount of magnetism is developed. This, by the operation of a well-known law, sets up a current of magnetism in the copper wire, which is conducted by the telegraph wire to an identical apparatus at the other end, the magnet of which in itself attracts more or less strongly the plate of iron, and the vibrations of this plate cause the disturbances in the air in front of it, which, acting on the tympanum of the ear, produce sounds. Having stated that the plate is only as thick as a sheet of note-paper, and when we add that this is removed from the magnet but the thirty-second part of an inch, our readers will easily understand how slight the variations must be of the magnet in front of it, and accordingly how small must be the current transmitted to the receiving telephone. But although this is so, those who had the advantage of being present on Wednesday were able to hear distinctly the sound of voices, and the music from a small child's instrument, which Mr. Francis Fox, at Huntcliff, played. It will be clear that until means are discovered for preventing the action of the "induced" currents from the neighbouring wires,

of which we have spoken, the telephone is not likely to pass into ordinary use, but the ingenuity of telegraph engineers is so great that we venture to predict they will either succeed in preventing this action or in strengthening the current produced by the telephone so as to overcome this difficulty."

On another occasion we made half a dozen people hold hands, and spoke through them, they forming part of the circuit; then we measured their electrical resistance in ohms, and found that robust and healthy persons had less electrical resistance than those who were not robust; and thus we were able to make a tabulated statement of all the persons in circuit, and give the equivalent number of miles of copper wire for each individual.

We also had in August, 1877, one of the first phonographs patented by Edison a month previously, which in those days recorded the impressions on tinfoil. Amongst the many curious experiments was the superimposing two or three voices on the same record. Thus one person would speak on to the cylinder; it would then be turned back to its commencement, and some other person would sing on to the tinfoil; a third person would recite poetry. When the sound was given off, we only heard a

confused compound of all three, just as one hears in a room when three persons are all speaking together; but if we decided to listen only to No. 1 we could hear him distinctly—and in like manner No. 2 or No. 3.

Whilst upon electrical matters, I desire to place on record what is believed to be the commencement of electric cables.

In 1837 the first line of practical telegraph ever constructed was laid down beneath the permanent way of the London and Birmingham Railway (now the London and North-Western) for working the traffic between Euston and Camden. It consisted of a length of deal cut to a section somewhat triangular, in which five wires were placed in grooves, which were then filled with wedges, tarred all over, and buried in the ground.

It was laid down under the directions of Mr. Cooke, of Messrs. Cooke & Wheatstone, and was worked by the five-needle instruments patented by them on June 10th, 1837.

The accompanying photograph represents a small portion of it mounted on a stand, kindly given to me by Sir William H. Preece; the timber was $2\frac{1}{4}$ in. wide at the base, 1 in. at the top, and $2\frac{1}{4}$ in. in depth.

The following is a partial copy of the original

invoice for the work, certified by my father in 1837:—

LONDON & BIRMINGHAM RAILWAY COMPANY.

To WILLIAM & LEWIS CUBITT.

For Sundry Works done at the Euston Grove Station, etc., in attending upon Mr. Cooke, and assisting to fix Wires and Woodwork, etc., for Signals, or the Electrical Apparatus, etc.

		£	s.	d.
1837.	From Sept. 16th to December 23rd.			
	Various items	100	10	1½
	5,524 ft. run: fir in scantling sawn triangular, and grooved for copper wires, including all labour to preparing and tarring same over and tar to do.	69	1	0
	27,620 Deal Tongues to do. do.. .	18	8	3
	Tar for bedding the fir in at the Extension, etc..	1	15	0
		£189	14	4½
	Other items . .	9	17	9
		£199	12	1½

C. FOX.

A portion of this so-called "fossil" telegraph was dug up a few years ago, and it was used on Tuesday, June 22nd, 1897, at the Jubilee of our beloved Queen Victoria, to form a portion of the circuit through which Her Majesty signalled her

Portion of the First Telegraph.

Consisting of five wires embedded in wood; laid between Euston and Camden Town Stations on the London and North-Western Railway, in Sept. 1837.

[*To face p.* 128.

instructions to forward her message to all the Colonies, which was as follows:—

"From my heart I thank my beloved people. May God bless them.

"V. R. I."

Engineers have frequently to use the boring tool to find water, or to localise mineral, and in connection with this subject many curious and interesting results have been obtained. There is no branch of work which requires greater care and vigilance than this, and the safe rule to be adopted is that the rods, at the end of which the boring tool is fixed, shall not be brought up from the bottom except in the presence of the engineer. A few years ago an important boring was being made for coal, and the men brought up some very fine samples, and these indicated a thickness of seam of 8 ft. Thereupon a company was formed, machinery erected, and a couple of pits sunk at great expense, and to the depth of 250 yds. When the coal was at last reached, it was found that the borers had one night simply plugged the bottom of the hole with coal thrown in from the surface, and which consequently the tool had brought up as a sample; but the actual seam of

coal had no existence, except in the fraudulent intentions of some one on the spot.

It is not a rare occurrence for the boring tool to become detached or broken off from the rods, and although there are many and excellent devices for recovering the lost part, or, as a last resource, of breaking it up into fragments, yet one's efforts are often fruitless; the hole has to be abandoned and a new one commenced.

The late Mr. W. H. Barlow, the Engineer-in-chief of the Midland Railway Company, gave me the following interesting account of a boring for water which that company was carrying out in the North of England some years ago.

The bore-hole was only 6 to 8 in. in diameter, was full of water, and had attained a depth of 600 ft. when the tool broke, became detached, and remained fixed at the bottom. Every possible device was adopted for its recovery, but it proved immovable, and the hole was reluctantly abandoned.

A few days afterwards a working-man came into Mr. Barlow's office and said, "I understand you have lost your boring tool, and are abandoning the hole; but, before doing so, I have come to make the following offer, which if you accept will save the boring and all the expense which has been

incurred." Mr. Barlow asked what the conditions were, and the man said there were three. First, that a close fence, 9 ft. in height, should be fixed round the hole, to prevent any one seeing what was done; secondly, that a policeman should be on duty to keep inquisitive persons at least 50 yds. away; and thirdly, that if he brought the tool back he should receive £30.

As the offer was made on the "no cure, no pay" principle, and the company, in the event of failure, would only lose the cost of the fence, Mr. Barlow accepted the man's offer. When all was ready, the man went inside the fence, accompanied by a boy, and apparently took nothing with him but a long coil of rope. At the end of a few hours he walked into Mr. Barlow's office with the missing tool, and the hole was saved. The money was at once paid, and then he was asked how he had done it; he replied that it was his secret, and he did not intend to divulge it to any one. Mr. Barlow suggested that he should put the description into writing, so that future generations might benefit; but the man simply replied, "When I die the secret dies with me," and to this day no one has the slightest idea as to how this feat was accomplished.

CHAPTER VIII

UNITED STATES AND CANADA

Having visited these great countries several times, I cannot do better than recommend all others who have a chance of so doing not to lose the opportunity. The kindness and hospitality I have received from all I met are beyond description, and have left some of the happiest recollections behind them.

The closer Britain and America draw to one another, the better for the world at large. Canadians are our own kith and kin, and a portion of our Empire, whilst the Americans are our cousins, speaking the same language, and generally holding the same religion. We and they ought, therefore, always to be found on the same side in any great question which may arise amongst the nations of the earth.

We were at one time constructing some 400 miles of railway in Canada, much of it through

dense forest. In order to avoid the danger resulting from trees falling across the line, the forest is "slashed" for a width of 100 ft. on each side of the railway. At one particular place, where it was laid through a boggy part of the forest, I found a patch about two acres in extent of the hardy Pitcher plant (*Sarracenia purpurea*), and the embankment, some 10 ft. in height, was made of peat from side-cutting. We were travelling some miles up country, but on our return found the forest on fire, and in full blaze, it having traversed a distance of 70 miles from some place north of the railway.

The flames were up to the tops of the fir-trees, and vast volumes of smoke and sparks were blowing across the embankment. We had hoped that this clear belt of 200 ft. would have arrested the progress of the fire, but unfortunately the ground, consisting of dry peat, carried a smouldering fire to the railway, and we had to dash through on the locomotive, protecting our faces and hands with coats and wraps, and thus escaped. Immediately afterwards the embankment got alight, burnt up the sleepers, permanent way, and fencing, and set fire to the forest on the other side. Away the flames swept on their resistless course, sparing no

clearing or settlers' shanties in its path, and too often destroying the settlers themselves, and their belongings. It was pathetic to see the game, rabbits, and hares taking refuge on the railway, with their fur singed and feet burned.

With all its wonderful resources of natural oil, natural gas, natural soap, with its copper ore so rich that it cannot be blasted, with its magnificent deposits of iron ore, of such high quality that no one will be surprised if before long steel rails are found already rolled lying in the ground, America does not possess any chalk. It seems as if it had been left out of the geological formation, and consequently she has to draw her supplies from Europe. One curious result of this is, that much of the straw used by the Americans for their iced drinks comes from England. At first sight this is difficult to account for, seeing that America grows unlimited quantities of wheat straw. But the same reason that fixes the straw hat manufacturer at Luton, Dunstable, and elsewhere, accounts for English straw being used in America. Wheat straw which is grown on chalk land is particularly strong and crisp, and is coated with a beautiful external skin of flint glass, making the tube of the straw quite air-tight, and giving it a

very bright and attractive appearance. This is due to the plant taking up flint in solution from the ground, which, being chalk land, is full of this natural silica, whereas straw grown on the prairies and on light alluvial soil has no flint to feed upon.

During this visit to Canada, and whilst in Toronto, I heard of an old schoolfellow named S——, who was in trouble. He had been with me at a certain public school in England, and had, in fact, been my "fag." I treated my fags leniently, and gave them so little to do that there was competition amongst the small boys to serve me in that capacity, as by so doing no one else could have them. Most of them strongly disliked being sent out to field at cricket practice, or to fag at racquets, and preferred on cold days to sit in my study, and roast their potatoes at the fire. S—— was in my form, carefully keeping near the bottom by his idleness and inattention.

Ten years later he was selling papers at Toronto railway station to earn a living, then tried his hand at "lumbering" in the Canadian forests, but being small in muscle, gave it up and went to New Orleans, and obtained work on the "Levee" or river bank as a labourer. He had not written home for eight years, and was practically lost.

I had to visit Indiana on railway business, having to report on a projected north and south line 200 miles in length, and since built, between Chicago and Evansville on the River Ohio. It was blazing hot weather, 100° in the shade, and malaria was rampant. About a hundred miles of the distance was finished by Friday night, and it would occupy another week to complete the remainder of the route. As I always avoid working on Sundays unless absolutely necessary, I felt it was imprudent to remain in a fever-stricken district from Friday night to Monday morning; and as I had "struck" an east and west railway at Terrehaute, I decided to take the cars going west, to Saint Louis, and there spend Sunday quietly, and secure an opportunity for attending divine service.

I had intended to stay at the Southern Hotel, then the best in the city; but in the train a passenger strongly advised me to go to another hotel, and, much against my will, I went. I had a comfortable room; but on finding that the passenger proved to be the landlord, I nearly decided to leave, but eventually agreed to remain.

On Sunday at dinner the large dining-room was filled with people, sitting four at a table; and turning round by mere chance between the courses, I

noticed at the other end of the room a poor sickly man enter, in his shirt sleeves, carrying a stack of plates piled up under his chin.

Something in that man's face attracted my attention, and I sent the waiter of my table to fetch him. This he did very reluctantly, saying that he ought not to have entered the room at all, as he only cleaned the knives.

However, I insisted on his being brought to me, and he came, this time with his coat on.

I spoke to him. "Do you remember me?"

"No, but I seem to recollect your voice."

I said: "You are an Englishman named S——. You were at a certain public school in England."

"Yes."

Some excitement was by this time aroused amongst the waiters and guests, so I let him go then, and afterwards brought him into my bedroom. He gave me his history, and wound up by saying that his was a complete parallel to the case of the prodigal son, and he only hoped the end would be the same.

At school S—— had been one of the smoking, drinking clique, and a fellow I never liked; but his history was a sad one. He was a nephew of the head master of a public school, cousin to one of

our leading London bankers, into whose bank he entered. After some years there, he ran away to America with a brother clerk, both intending to make their fortunes; but their money melted. They tried everything, and gradually sank through the various grades to cattle-drivers, railway navvies, timber men, and finally S—— had to clean boots and knives in the hotel.

I found him in the depths of despair and on the point of suicide. He said to me, "Do you remember when at school you were in the sixth form and had a study, and on wet days you allowed your fags to sit by your fire and cook their potatoes?"

"Yes, now you mention it, I do."

"Well, come and see my study."

He took me into a kind of scullery, lifted up a trap-door by the ring, and then I saw a step-ladder, going down into an apparent abyss of darkness. He told me to follow him, not to be alarmed, mind my head against that beam, and not to rub myself against the walls, which were covered with fungus and cobwebs.

The underground passage led beneath the pavement of the street, where, lighted by a flag of thick glass, was his knife-board and stool; and here from

5 a.m. until 6 p.m. he sat cleaning knives, the rats his only companions.

I hesitated as to getting him back to England, but gave him money and clothes, found him more respectable employment, and wrote to his friends at home. Three months afterwards he called upon me near Liverpool, having worked his way across the Atlantic in charge of cattle, and when last I heard of him he was doing well.

Had I not been driven from the forests by the fever and been directed to the wrong hotel, and had not, at dinner, turned round exactly at the right moment, I should not have seen him; but I feel that I was guided, and thus was the means of rescuing him from a miserable existence, or death.

On my way back to New York I witnessed a sad and remarkable fire in the oil regions, where some large oil-tanks, holding 2,000 tons of petroleum each, got alight; soon afterwards a railway train of thirty oil-cars was also in a blaze, destroying everything within reach, leaving only the steel rails bleached and twisted like tangled cotton, and the driver and fireman, badly burned, lying on the ground.

This was a great contrast to what we had

experienced when on our voyage from Liverpool to New York in January. We were in a terrific gale in the "rolling forties," battened down, with the seas going over the funnels, whilst the thermometer stood only a few degrees above zero. The result was that the ship was enveloped in ice from deck to truck: every rope was encrusted ten inches thick, the boats were frozen in pedestals, and all the forward part of the ship was three feet thick in ice on the deck.

After the gale had blown itself out, the sun came out, and the appearance of the ship was lovely in the extreme; she looked for all the world like an Arctic exploring vessel.

Certainly the impressions I have received from my various visits to America enable me to corroborate the remark of an Irishman, who on being asked whether America, to which country he had emigrated, was a good place for a working-man to go to, replied, "Faith, it is: when I first went I hadn't a rag to my back, and now I'm just kivered with 'em."

Canada especially offers great attractions to industrious and steady men, and also the prospect of happy homes to large numbers of the young women of our country.

CHAPTER IX

SOUTH AMERICA

THOSE who wish to realise what the great continent of South America is must refer to the many books of travel published on the subject. Humboldt's and Darwin's writings will give much information, and I do not attempt to do more than describe a few incidents of my own journeys.

Pernambuco, where I first landed, is protected from the sea by a coral reef running parallel to the coast, which encloses a kind of smooth-water lagoon in which vessels can lie with safety; but, as the entrance through the reef is very narrow, the mail steamers lie outside, exposed to the roll of the sea. Whilst the vessel was lying outside the fourth officer was having a game at "hide-and-seek" with some children on board, and in the midst of the fun a little girl fell overboard. Although the sea was swarming with sharks, showing their back fins above water, the officer

instantly jumped overboard, and held the child up until both were rescued by a boat lowered from the steamer. On my remarking to the officer that he deserved a medal, he replied that the only thing he did get was a "wigging" from the captain for skylarking.

The sharks generally keep a few yards from the ship, round and round which they swim all day long, and it was probably due to their fear of coming too close that both officer and child were saved.

Whilst in Pernambuco I met, by chance, a young Englishman dressed in "duck" and with a broad-brimmed hat. He at once, with the invariable hospitality of our countrymen abroad, asked me to come and share his luncheon, which I was nothing loth to do. He told me he had come out with some cotton-presses from Lancashire for the plantations, but that, so soon as he had completed them, he had fallen in with some very good luck. It appears that the Brazilian sugar-planters had established very large and costly mills and machinery, employing many hundreds of hands; but as the Brazilians are not a mechanical people, break-downs were constantly occurring, due in many cases to the simplest causes, and to the

From a Water-colour Sketch by] [*F. Fox*, 1888.

THE HARBOUR OF RIO JANEIRO.

With "Sugar Loaf" Mountain near the entrance.

[*To face p.* 142.

ignorance of the staff. This young man told me that he was frequently being called upon, in great haste, to see what was wrong, as the whole plantation and mills were idle, and he found that by the use of an oil-can and a "spanner" he could generally restart the machinery. He was appointed at a good salary by each of five or six plantations to keep them going, and this he did by paying them a visit about once a month.

Lying out in the Atlantic some considerable distance from the coast of Brazil is the island of San Fernando de Noronha, used as a penal settlement. It is stated that a Brazilian man-of-war was sent, some years ago, to survey the island, and returned with the report that it had sunk into the sea, and not a vestige left behind. The fact was that, owing to bad navigation, the captain had failed to find it.

On our way south we entered the harbour of Rio Janeiro, which is one of the finest in the world; it is, in fact, an inland lake surrounded by high mountains, the entrance from the sea being the narrow channel just above the stern of the steamer in the accompanying sketch. The celebrated Sugar Loaf mountain guards, as it were,

the southern side of the entrance, at the base of which are strong forts.

Some six or eight miles in the country outside Rio, and at a considerable elevation, is the lovely suburb of Tijuca, with its palms and plantains, its wonderful tree-ferns, and also its creeping fern, one end of which is said to be at Tijuca and the other at the Andes, over 2,000 miles distant, and only stops there owing to perpetual snow.

Yellow fever was beginning to claim its daily victims whilst I was in Rio, and when I finally left the city over 1,000 deaths a day from that fell disease were recorded.

From Rio we travelled to St. Paulo, a journey of twelve hours by rail, and it was on this occasion that a startling occurrence took place. My daughter and I were sitting in a first-class carriage, with our backs to the engine, each by a window. Opposite to each of us, in the other corners, was a Brazilian. We travelled from 6 a.m. until noon, when we stopped at a junction, and during the whole of that time not a word was spoken by either of our fellow-passengers. As soon as the train stopped, the man opposite to me alighted, and the train proceeded, leaving one Brazilian sitting opposite my daughter. Very slowly and

From a Water-colour Sketch by] *Francis Fox*

"SALINA BLANCA"—OR DEPOSIT OF WHITE SALT—IN NORTHERN ARGENTINA.

Said to be 300 miles long by 50 miles wide.

[*To face p.* 144.

deliberately he drew out from the breast of his coat a long, naked butcher's knife, and held it in front of him. Whether he intended to attack us or not we could not say, but it looked ominous. Then he put his other hand into the opposite pocket, and, with equally slow deliberation, he drew out a sheath, and put it over the ugly, threatening blade, and then replaced it inside his pocket, buttoned up his coat, and relapsed into sleep. He had evidently been waiting, in an expectant and prepared condition, for the possible event of his fellow-passenger attacking him.

The use of the knife and revolver was unfortunately very common in South America; but it is seldom that Europeans are the sufferers, the victims being generally those involved in some long-standing family feud. At a particular city, when I was there, no less than fifty-two prisoners were charged with murder, and I remarked to my friend, a leading man in the place, "I suppose they will all be executed?" and he replied, "Oh dear no! the ladies invariably get up petitions for the men's pardon, and the probability is that within a month fifty will be released; the remaining two, who perpetrated specially brutal murders, will be drafted one into the army, the other into the police."

Our next visit was to the Argentine Republic, and as we neared our destination, Buenos Aires, we were naturally anxious to know what sort of country it was to which we were going. We were informed that it was almost dead level for 500 miles north and south, and for nearly 1,000 east and west. As the present docks were not completed, the steamer anchored in the great estuary of the River Parana, 12 miles from Buenos Aires, whence we were conveyed by a tug-steamer to the shore. We soon found the country to be absolutely flat, and noticed the very remarkable effect of mirage, the horizon presenting the appearance of an estuary of some river, with vessels upon it, whereas no water really exists.

I spent some days in Buenos Aires, which is a wonderfully prosperous city, now greatly assisted by its docks and railways. Its formerly narrow streets are giving place to fine wide avenues, and beautiful public gardens extending for miles.

We had to proceed to Rosario, 200 miles up the river, and whilst there saw the extraordinary results of a great flood in the Parana, which at this place is 30 miles in width, consisting of a number of channels, each about a mile and a half

From a Water-colour Sketch by] [*Francis Fox.*

THE RIVER PARANA.

From the top of the cliff or barranca at Rosario.

[*To face p.* 146.

wide, divided by low, narrow, and thickly wooded islands.

The river was in heavy flood, there having been great rains in the interior of Brazil, in consequence of which the swamps, some 1,500 to 2,000 miles farther inland, had been buried under the water. The brushwood had floated out above the trees, carrying with it innumerable parasitical plants, orchids, and other tropical growths, which matted these accumulations of wood into floating islands. The wild beasts of the forests, as the water rose, took refuge on these rafts, and as many of them were two or three acres in extent, and several feet in thickness, they were able to carry their living burden without difficulty.

A struggle for existence doubtless went on during the long voyage down the Parana, lasting for weeks, and we could see the rafts passing down carrying pumas, jaguars, and other wild beasts to sea. One of these floating islands came ashore under the wharf of the Central Argentine Railway Company, alongside which were lying two large merchant steamers. The animals at once rushed on to the land, and made for the town in search of food. The people turned out with guns and revolvers, and there was a regular wild beast hunt.

I was on the wharf soon afterwards, and seeing some lovely orchids in full bloom amidst the brushwood, was on the point of climbing down to get them, when the captain of one of the steamers shouted out, "Don't go near it: one of my crew has been killed this morning, and another seriously injured, by deadly snakes, hidden under the leaves: they are hungry, and will at once attack you."

Needless to say, I left the flowers alone.

One day the general manager of the Central Argentine Railway had taken us from Rosario to a large city some 300 miles distant. On arriving at our destination we found the night express just about to leave for Rosario, on the return journey. Fortunately we did not remain at the station, for within the short period of ten minutes, from the time we arrived to the time the express was to start, the following occurrence took place.

A brougham drove up, bringing a newly married Argentine couple, who were going by the mail train. The gentleman placed his bride in the train in a reserved first-class compartment, and was standing smoking a cigarette, waiting for the train to start when a second brougham drew up, out of which stepped another Argentine, who proved to be

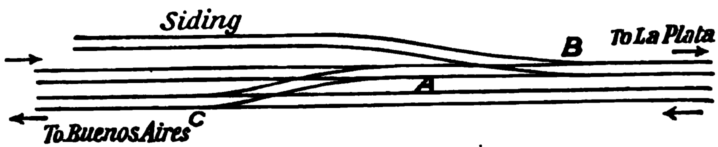
From a Water-colour Drawing by] [*Francis Fox.*

MIRAGE ON THE PRAIRIE OR "CAMP" IN ARGENTINA.

Sketched from the Central Argentine Railway.

[*To face p.* 148.

the uncle of the bridegroom. He at once made off for the mail train, and seeing his nephew on the platform, drew his revolver and shot him. The poor young man fell, and, rolling over, had sufficient strength to draw his revolver and to shoot his uncle, both dying on the platform under the eyes of the bride before the train started. Such painful incidents are, however, passing away, and Europeans can now live in Argentina with as



PLAN OF RAILWAY BEFORE ALTERATION.

profound a sense of security as they can in London.

The railway between Buenos Aires and the capital, La Plata, interested me greatly. It had been built by English engineers, according to ordinary British practice, as a double line. Thus the "up line" to La Plata was on the left-hand side, the "down line" on the right-hand side, all the crossovers and sidings being properly laid with "trailing" points. The accompanying sketch will illustrate what is meant.

A and B are trailing points on the metals leading to La Plata, and C on those going to Buenos Aires; but by order of the authorities this had to be reversed, and the trains had to travel on the opposite lines. The result of it was, that every trailing point became a "facing" point, and being unprovided with any interlocking safety appliances, constituted at once a grave source of danger to the traffic. Not long afterwards an express, in which the governor of one of the provinces was travelling, was switched into a siding, but beyond smashing up some trucks which were standing in it, no damage was done, owing to the promptitude of the driver in applying the brakes. He found himself arrested for running on the wrong road, but was rewarded by the governor for his presence of mind, as it was felt that some one had intentionally turned the train into the siding in order to kill his excellency.

The Argentine railways are generally highly prosperous, but they are exposed to extraordinary vicissitudes. Owing to the extreme flatness of the country, and the soil being all alluvial, sometimes a gale of wind buries a train in the light, black earth which it carries before it; then the rain comes, and flows off the land so slowly, owing

THE MADERO GRANARY, BUENOS AIRES.

Capacity, 80,000 tons.

[*To face p.* 150.

to the distance of the rivers apart, that it has been known to stand two or three feet deep on the "camp" for miles, turning the soil into mud.

Locusts occasionally visit the country, not only causing great injury to the crops, but stopping the trains in consequence of thousands being crushed under the wheels, which thus fail to get the necessary adhesion, owing to the rails becoming lubricated. Increased cultivation of the land promises to reduce this locust plague in the future.

The accompanying photograph of an extensive building in the Madero docks at Buenos Aires is that of one of the largest granaries, if not the largest, in the world, which we have recently designed. It is more than half a mile round, and will contain 80,000 tons, or 3,200,000 bushels of grain, part in "bulk," the remainder in bags, and is fitted with every imaginable kind of labour-saving machinery. The Argentine papers described it as being "designed by the well-known American engineer, Francesco Fox." Fortunately Englishmen are capable of designing and erecting such structures, which are needed both in England and in many British Colonies, and a description of which will be found in the next chapter.

I have appended photographs of some water-colour sketches which I made during my various journeys, and which may prove to be of some interest. The one opposite page 144 represents the great Salina Blanca, or deposit of salt in the Argentine, between Cordova and Tucuman. This is said to be 300 miles in length and 50 in width, and looks like a great inland sea.

The next, facing page 146, is a view of the River Parana from the barranca, or cliff, at Rosario. The width, including the low islands, is about 20 miles, and my sketch was made with the intention of explaining the system of vessels lying under the cliff and being loaded with grain by shoots. Vessels in the distance are shown as passing up and down stream; but evidently the perspective did not appeal to the mind of a little girl to whom I showed the sketch, for she innocently asked, "Please. why do they hang up the little models of the ships in the rigging?"

The view opposite this page is that of the Andes and the great peak of Tupungato, 22,329 ft., when seen from a distance of a hundred miles.

From a Water-colour Sketch by] *[Francis Fox.*

THE ANDES, WITH MOUNT TUPUNGATO (22,329 FT.), NEAR MENDOZA, ARGENTINA, 100 MILES DISTANT.

[To face p. 152.

CHAPTER X

THE MEDITERRANEAN

In 1865 I was travelling through Spain with a friend, and after passing through Miranda, Madrid, Cordova, Seville, Toledo, and other places, arrived in one of the large cities. We desired to attend a place of worship on Sunday, but as no Protestant church was then allowed by the Spanish Government, we went to the English consul's house, where we found he was to hold a service. Besides the members of his own family and servants, we were the only attendants, and so soon as we began to disperse, he came up to me and asked as to our movements.

In consequence of the "*Tornado* difficulty" (which vessel had been seized by the Spanish Government as a Cuban blockade-runner) threatenings of war had arisen between the English and Spanish Governments; his letters and telegrams were intercepted; and so, as we were going

overland to Gibraltar (there being just then no steamer), he asked me to carry a despatch, which I gladly consented to do.

We understood that there was a firm roadway as far as Algeciras, with hotels at intervals, but we were soon undeceived upon this point. We started at 4 a.m., driving some eight miles, and then proceeded again on horseback, with a mule to carry our baggage, led by a guide. We found that a fine road was being made, but no one was allowed to travel on it until its completion, and as it extended for only a few miles it made but little difference. It soon came to an end, and then we found ourselves in a thickly wooded country, traversed only by meandering foot- or bridle-paths; no hotels, and no food to be obtained.

At six o'clock the guide brought us to a wretchedly dirty posada, or country inn, which consisted of one room, serving the purposes of dining-room, bedroom, kitchen, scullery, and almost cowhouse. The landlord looked such a villainous cut-throat that I, knowing something of brigands, refused to stop there, and insisted on going on. Both the landlord and the guide were indignant, but I adhered to my resolve, and we left.

We pushed on as far as we could in hopes of

reaching some village, but night came on, the forest got much more dense, and innumerable large rocks were scattered about in all directions, some as large as a house, most the size of an ordinary room. To find our way was impossible; and as it began to rain, I ordered the guide to unstrap the baggage, and put it under a rock, and we began to make preparations for spending the night as best we could.

At that moment I saw a glimmer of light through the trees, and, making our way to it, found a miserable cottage belonging to a poor old cork-cutter and his wife. Finding the plight we were in, they most generously offered us what shelter they could, and gave up their own bedroom to us, although we, as far as our knowledge of Spanish permitted, protested against their doing so.

The first thing we required was food, but of this they had none—no bread, no meat, no eggs, but only Indian meal fried in olive oil, and which to us was uneatable. We searched our baggage, and, as we had made no provision for the journey, having been told we could get eatables on the route, the only food we could find was two hard-boiled eggs, a few biscuits, and two penny sticks

of chocolate. And this had to keep us going until we reached Gibraltar, however long that might take.

The man and his wife could only boil water in their frying-pan, which evidently had not been cleaned for years; and as the fuel was cork, it took a long while to get hot water.

The question of sleeping was difficult, not merely from the fact of the bed being somewhat hard and rustic, but chiefly because of the black-beetles and vermin with which the place swarmed. Sleep we could not, and at 3 a.m. we roused our guide, and, telling him we intended to start, he reluctantly got up and saddled the horses; and after heartily thanking our host and hostess for their kind efforts, and remunerating them for their services, we started off, but none of us knew where we were, nor in which direction Gibraltar lay.

I decided therefore to climb the adjacent mountain, and with my compass find out what I could. On reaching the top, about daybreak, I was gladdened by the sight of Gibraltar, lying like a crouching lion, right away on the horizon, some forty miles distant in a bee-line.

We went in the required direction, and although

we had to go round the Bay of Algeciras, and were hindered by one of the horses casting a shoe, we were able to reach the neutral ground in time to enter the fortress before gun-fire, failing which we should have had to lie outside the walls all night.

On arriving at the British lines, we felt proud of being English, our baggage not searched, our word accepted, whereas our guide was told he must return within twelve hours. We went through the gates and under the guns, and soon in the main street met English officers and their wives, soldiers and bluejackets; and, on arriving at the Club House Hotel, enjoyed such a dinner as we had not had for many a day.

The despatch, which I had hidden on my person, was duly delivered, and the governor appointed one of his aides-de-camp to look after us, extending to us much hospitality, and showing us everything of interest.

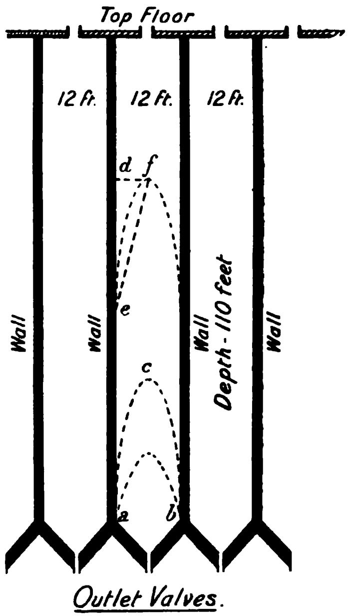
A few weeks later two Englishmen were taken by brigands, and held for six weeks for a considerable ransom. They afterwards wrote an account of it, but briefly the facts were these: they were harried from place to place, and threatened to be shot; but as the English Government insisted on the authorities ransoming them, this was done.

The money was placed on a rock, and on the return of the party the captives were found at the appointed place.

Being much interested in the storage of grain, I went on to Malta, to see the granaries for keeping a stock of wheat in the island in case of war. These are large pits, excavated in the ground in a public square, the entrance to each pit or "silo" being covered with a block of stone. A special department works the grain storage, so as to ensure the wheat being kept in good condition.

These pits probably resemble those in which Joseph stored grain in Pharaoh's time, and are the forerunners of the system of grain silos now in extensive use in England, America, the Continent, and elsewhere. The modern system is to erect a large structure, consisting of vertical bins or silos, 10 to 12 ft. square, and as much as 110 ft. in height, the grain being taken, in bulk, out of ships and raised or "elevated" (hence the name "grain elevators") up into the roof. Here it is thrown through spouts on to endless indiarubber belts, varying from 18 to 36 in. in width, which convey the grain to any particular silo, where it is again thrown off and stored. It remains in this silo until it is required, when it is allowed to escape

through a valve in the basement, on to other endless bands, which remove it to railway trucks,



SECTION OF GRAIN SILOS IN A GRANARY.

or vessels, or to the bagging-floor, where it is done up in suitable bags for carting away.

In connection with these silos some remarkable facts have been recorded which are worth knowing, and which the accompanying rough sketch may serve to illustrate. This represents a vertical section of a

bin, say 12 ft. square and 110 ft. deep and constructed of brick or fortified concrete, thus presenting a somewhat rough surface, and producing friction or "stiction" between the grain and the walls. If it be filled with grain to the top, it is found that the maximum pressure on the bottom is attained when it is about one-sixth part full.

Thus if *a b* be the width of the bin, and a point *c* be found at a height approximately of double *a b*, the total quantity of grain resting on the bottom is represented by the figure *a b c*. Nearly all the remaining grain above that triangle is carried, as a vertical load, by the side walls. It seems as if the grain formed itself into a series of invisible arches as dotted, the length *d e* representing the vertical load on the side walls, and the length *d f* representing the horizontal or bursting pressure.

But now comes a remarkable discovery. It was found that, if any vibration or earth tremor takes place, the grain consolidating would, contrary to anticipation, produce a reduced pressure on the bottom, and transfer it to the side walls—in fact, the arches become reduced in height as indicated. The following figures illustrate this:—

Bin containing 300 tons of wheat: weight on

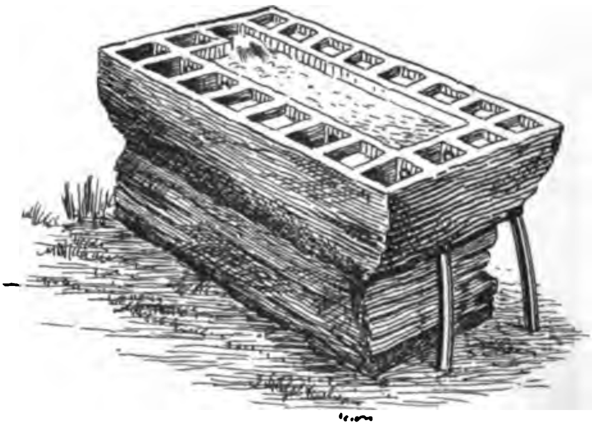
bottom 90 tons, the remaining 210 tons hanging on to side walls. After vibration: Weight on bottom 66 tons, remaining 234 on side walls. In other words, the load on the bottom is reduced by tremor 26 per cent., thus pointing to the necessity of making all walls of granaries and silos sufficiently strong not only to act as divisions between wheat and maize, or maize and oats, but capable of practically carrying as a vertical load nearly the whole contents of the granary. Ignorance on this subject has doubtless been the cause of the bursting of many such buildings. Much more could be written on this subject, but it becomes too technical.

On the coast of St. Paul's Bay, Malta, is the spot on which the Apostle's shipwreck took place—the "place where two seas met."

On another occasion, whilst visiting Constantinople, I saw one of the saddest spots in the world, known as "The Castle of the Seven Towers." This consists of a courtyard surrounded by high walls, on which are seven towers: in one of these is a dungeon in which ambassadors, sultans, and others were imprisoned, tortured, and put to death, and it is pathetic to read the touching inscriptions scratched on the walls on either side

of the door. Three almost illegible inscriptions are given on opposite page.

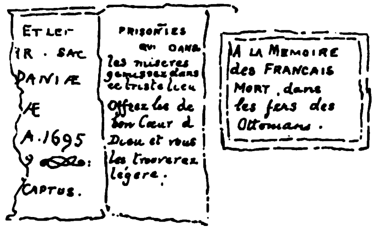
On the aqueduct in Stamboul is to be seen the interesting method for distributing the water to the various houses—viz. a number of stone tanks with divisions called "Taksim," into which the



AQUEDUCT IN STAMBOUL.

water flows, each sub-division representing a different consumer. Should any one not pay his water-rate, the water is cut off by his partition being plugged up: hence the reason why some are seen to be empty.

My readers will notice that I do not attempt to describe the various cities through which I



SOME OF THE INSCRIPTIONS WRITTEN ON THE WALLS OF "THE CASTLE OF THE SEVEN TOWERS," CONSTANTINOPLE, BY THE UNFORTUNATE PRISONERS.

From a Water-colour Sketch by] ↑ *F. Fox.*

THE COURTYARD OF "THE CASTLE OF THE SEVEN TOWERS," CONSTANTINOPLE.

In which ambassadors, sultans, and others were imprisoned, tortured, and put to death. They were confined in the tower, and entered through the door indicated by the arrow: their touching inscriptions are to be seen on each side of the door.

[*To face p.* 162.

travelled, as this has already been done by far abler pens than mine. I merely draw attention to certain features which were of particular interest to myself as an engineer.

A journey up the Nile has so often been described that this again will not be attempted here, but certain objects of interest remain depicted in one's mind. Whilst in Cairo I naturally visited the great collection of antiquities, first kept at Boulak Museum, but from which it was removed, for fear of the whole place being swept away by a Nile flood, it having been found that there was a depth of 72 ft. of water just outside its walls. It was then placed at Ghizeh, in a palace built chiefly of lath and plaster, and occupying sixty-seven separate rooms, where an attempt was made to rifle the collection, the thieves covering their escape by endeavouring to set the place on fire. I called on Col. Sir Colin Scott Moncrieff, who with laudable effort had done all in his power to protect the museum; but so serious did I consider the danger of fire that after seeing him I interviewed Lord Cromer, and urged that it should be properly housed in a suitable fire-proof building. It is a matter of congratulation that he has seen his way to impress upon the

Khedive the necessary provision by the Government of a suitable museum for these priceless and unique treasures. One fire at Alexandria was sufficient to destroy its great library, and a similar fate would have awaited these papyri and records, from which alone the history of Egypt could be written, had not the representative of Great Britain brought pressure to bear upon the Egyptian authorities.

One day I was on the Great Pyramid with my dragoman Abdullah, and I lent him my field-glass, he never having seen one before. He looked through it, then looked without it, and in his broken English said, "It do bring de tings quite near." He turned it upon his mud shanty about a mile away, and I heard him say, with surprise, "Ah, dere are my two vives, playing like two leetle kittens."

"Oh! Abdullah, so you have two wives, have you? How do you get on with them?"

"Oh! dey be berry good, berry good: I give them stick, much stick."

At Luxor I went to the workshop of an Arab who manufactured false scarabs. He made no secret of the trade—showed me his genuine and original ones which he copied, and which he

would not sell; then showed me his rough pieces of soapstone which he gradually shaped and engraved, and finally, to make them look more ancient and worn, fed his turkeys upon them, so that the edges got rounded off in passing through the birds' gizzards, and a somewhat more genuine appearance was imparted to them.

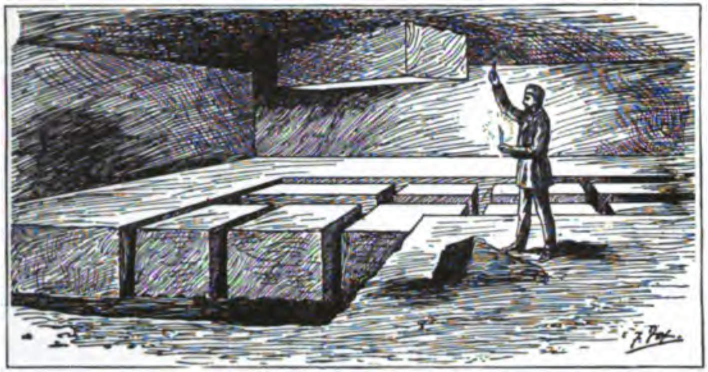
We were invited one afternoon to tea in No. 16 Tomb at Beni Hassan by a friend engaged in copying the wall paintings and hieroglyphics of that place of burial; and it was a matter of surprise to us, as it still is, how such paintings were executed in underground chambers, in many cases hundreds of feet within the mountain, where daylight could not reach, no sign of artificial light or of smoke of candles or lamps being observable. Whilst at Beni Hassan our friend discovered on the walls amidst the hieroglyphics a small inscription about the size of a postage stamp, written in demotic characters, the ordinary language of the people, and which evidently had no connection with the subject of the paintings, but was rather a communication from one artist to the other, and which read as follows: "Let us knock off work, and go and bake some bread." Probably

these artists were slaves, and worked in silence, and therefore wrote on the wall what they wished to say to one another.

At the Great Hall of Columns at Karnak are the remarkable windows in which some of the great stone bars still remain, and close by are the two obelisks (one broken), which are no less than 108 ft. long by 8 ft. square at the base, in one block of stone; whilst in the quarries at Syene is a half-worked block 110 ft. long by 10 ft. square.

In March, 1887, having obtained permission from the governor of Jerusalem, who sent an officer, a soldier, and a guide to escort us, two friends and I, with two dragomen, went to see the underground quarries from which it is believed Solomon obtained the marble for building the Temple; these caverns were also the refuge of the inhabitants of Jerusalem during the fearful sack and destruction of the city by Titus, A.D. 70.

They are entered from outside the Damascus Gate by a small, unimportant-looking doorway beneath the city wall, and we found ourselves in a large chamber a good deal resembling the Peak Cavern at Castleton. After going in about 150 yds., the guides prepared to return, but I told them I wished to go much farther in, in order



UNDERGROUND QUARRIES AT JERUSALEM.

Showing the blocks of stone partially quarried by the workmen of old: one block hanging from the roof, with holes provided for the wedges for detaching it; other blocks on the floor with chases cut between them, and with similar wedge-holes.

to see the half-hewn blocks of white limestone or marble, which were left *in situ* by the original quarrymen.

Without demur they proceeded, and after going up and down, and meandering about in all directions, we came to the blocks, one hanging from the roof and several half-hewn out of the floor, left by the ancient quarrymen, and showing well the method by which they excavated the stone.

So soon as we had seen all we required, and after making the accompanying sketch, we began to return, having gone some considerable distance. We now observed all the guides in a state of embarrassment: the path they had taken led up to a solid wall of rock. They started off again in another direction, and again were stopped by rock, whereupon I called one of my companion's attention to this, and then discovered that we were lost.

I recollected the story of the tutor and his students lost in the catacombs of Rome. They had been for a Saturday afternoon's excursion to see these ancient burial-places, but none of them ever returned; and this did not tend to raise our hopes.

I suggested that the first thing to do was to insist on four-fifths of the candles being

extinguished, otherwise we should be in darkness in half an hour. This was done, and we then began to search for the right route in some more systematic manner; but as the paths went in all directions, and the floor was covered with endless blocks of rock, it was a difficult matter to make sure where we had or had not been.

After a few minutes' search we all noticed a rock which we believed we had stepped over in coming in, and on the top of it we fixed a lighted candle. We next found another stone which we again recognised as an old friend, and on this placed another light. Thus we obtained the direction along which we had walked in coming in, and by means of a compass on my watch-chain we gradually worked our way back to a point from which we could see the welcome rays of blue daylight in the distance, and were soon outside, very thankful for our release.

When in Jerusalem one comes across innumerable incidents illustrative of Bible history. One of the most remarkable which I saw occurred when I was calling on a gentlemen, a German, living outside the walls. I went to his house, which has a small forecourt or garden in which shrubs were growing. I walked up to the front door, and was

surprised to find it sealed up, a strip of parchment being fixed by two large official seals, one on the door, the other on the doorpost, so that the door could not be opened without breaking one or other. At the same moment a tall Arab came out of the shrubs, and, holding up his great dark hand, told me to go. I found that some dispute had arisen between this German and the Government, and they had seized his house, "fixing a seal and setting a watch," just as was done to our Lord's tomb under the Roman rule.

Not less striking was my first introduction to the beds used in the Holy Land. Formerly, when I read of the man sick of the palsy being told to take up his bed and walk, I used to imagine it was a heavy four-poster, whereas I soon found that these beds are made of light basket-work, which can be lifted with the greatest ease—if not by one finger, yet by one hand.

CHAPTER XI

RHODESIA

In 1896 the Right Hon. Cecil Rhodes, in consequence of failure of the crops that year amongst the Matabele, gave instructions that the portion of the projected "Cape to Cairo Railway"—between Vryburg and Bulawayo—was to be opened for traffic if possible a year before the contract date. Sir Charles T. Metcalfe, Bart., the company's engineer in the colony, and Messrs. Pauling, the contractors, at once made arrangements for this to be done; and on November 4th, 1897, four long sleeping-car and dining-car trains arrived on their journey from Cape Town to Bulawayo, a distance of 1,360 miles, carrying some 400 visitors, including the High Commissioner, now Lord Milner, the Governors and leading men of South Africa, the Admiral, Commander-in-Chief, Judges and Members of Parliament, for the festivities connected with the inauguration. The girder

bridges over the chief rivers, such as the Shashi, the Orange, and the Crocodile, had not been fixed, and consequently the rails had been laid on the sandy bottom—a method only possible during the dry season—the trains running down one bank and up the other. The risk connected with this was the possibility of rain occurring and consequently of the rivers rising, in which event the trains might be caught between flooded rivers, just as poor Wilson and his troopers were in the first Matabele war. To guard against every possible contingency of delay, each train carried a car loaded with provisions for a month; but fortunately no flood occurred, and the proceedings passed off with great success and *éclat*.

It was on this journey that an amusing description of the locomotive was given by one of the Matabele chiefs. He had been persuaded with much difficulty, and by presenting him with food and gifts, to come up close to the train when it was stopped for the purpose of filling up its tanks with water at a wayside station. On seeing the engine, the chief remarked: "It is a huge animal belonging to the white man. It has only one eye" (the head lamp). "It feeds on fire, and hates work; but when the white man pumps it to make

it work, it screams. It comes from somewhere, but no one knows whence."

A steam traction-engine greatly puzzled the natives, especially when the driver went round it oiling the various parts. They described it as a "huge animal which evidently had the fever very badly, because the white man poured in medicine at so many parts of its body."

The construction of 500 miles of railway in 400 working days, and the bringing in of the heavy saloon trains of the Cape Government Railways on the actual date fixed a year beforehand by Mr. Rhodes, was a marvellous feat, but it had its reward in the receipt of a kind and thoughtful telegram of congratulation from Queen Victoria.

At a farther distance of about 270 miles north-west from Bulawayo, on the main line, are the great coal deposits of Wankie, said to extend over 300 square miles, and to vary in thickness from 7 to 20 ft. The quality of this coal is quite first-rate, being but slightly inferior to the best steam Welsh coal, which is exclusively used by our Royal Navy. It is a novel sight to see long trains of fully loaded coal-waggons travelling *towards* instead of *from* Cape Town, whence fuel had hitherto been obtained; and, as one of the engineers

From a Photo by] [*F. W. Sykes.*

VICTORIA FALLS OF THE RIVER ZAMBESI, AS SEEN FROM THE WESTERN END OF GORGE.

Height 400 ft., length of "lip" of fall 4,000 ft.

[*To face p. 174.*

remarked, it was quite a refreshing experience to find oneself once more in a colliery district.

Some 70 miles beyond Wankie the railway, April 25th, 1904, reached the Zambesi River and its wonderful Victoria Falls. These were discovered by Dr. Livingstone, accompanied by Mr. Oswell, in 1855, and have been well described and illustrated by Mr. Thomas Baines in his beautiful book. The height is 400 ft., or greater than that of St. Paul's Cathedral, and the width is about 5,700 ft., the actual "lip" of the falls being in times of flood about 4,000 ft., equal to the distance from Buckingham Palace to Westminster Clock Tower, or from the British Museum to the Marble Arch, thus being two and a half times the height of Niagara, and double the width. When the river is in flood, the volume of water is enormous, and even during prolonged drought it is very large, as will be seen by the accompanying photographs, which were taken just before the rains commenced.

The bridging of the river is a matter of great importance to the whole of South Africa, as it will, in fact, form the gateway into the country to the north. This bridge is being carried out by the Rhodesia Railway Company, under the supervision

of the company's engineers, Sir Charles T. Metcalfe, Bart., and Sir Douglas Fox and Partners, they being represented on the spot by Mr. Townsend, Mr. Tower, and Mr. C. Beresford Fox; the contractors being the Cleveland Bridge Company of Darlington, with Mr. Imbault as their engineer.

The bridge will consist mainly of one large steel arch, 500 ft. span, the rails being 400 ft. above the water in the gorge, which is believed to be 300 ft. in depth; and it is being built out piece by piece from each side, on the cantilever principle, until the two halves meet in the centre.

The first step taken was to get some kind of communication from one side of the gorge to the other, a distance of about 700 to 800 ft., whereas to go round entailed a journey of 10 miles. The engineers began operations by firing a rocket, to which a fine string was attached, across the gorge. After three attempts they succeeded, and by means of this string were able to pull a cord across, then a wire, and eventually a $\frac{5}{8}$-in. steel cable. This was fixed on supports and strained tight, and by means of a running pulley, and the formation of a "bosun's chair," persons are able to get across.

The following extract from my son's letter of

From a Drawing by] [*A Elder.*

THE ARCHED CANTILEVER BRIDGE IN COURSE OF CONSTRUCTION ACROSS THE GORGE OF THE RIVER ZAMBESI, NEAR THE VICTORIA FALLS.

Span 500 ft., height above water 400 ft.

[*To face p.* 176.

November 21st, 1903, is of interest, as it describes the first crossing of this mighty gorge of the Zambesi.

"VICTORIA FALLS
"*November 21st*, 1903.

"Well, I am crossing the gorge almost daily now by the wire rope: it is such a saving of time and trouble; but the first sensation is almost terrific. I was the first to cross, and did so from the north to the south side. The cable is a $\frac{5}{8}$-in. diameter steel wire rope, 900 ft. in length, and is supported at each side by a solid post 2 ft. in diameter, let down into the rock some 7 or 8 ft. Then a $\frac{1}{4}$-in. stranded wire acts as an endless hauling rope round a windlass at one side and a pulley on the other.

"The running pulley is, however, not quite satisfactory, as we could not obtain a trolley in Bulawayo, and so, temporarily, have to do the best we can; the present arrangement is safe, but not good mechanically.

"As they tied me into the 'bosun's chair' I must admit to feeling a bit strange in relying absolutely on my own calculations for my safety. The chair is a piece of wood suspended by four

ropes, with a canvas back and a sack and board as a foot-rest. Of course one is so tied in that were you to lose consciousness you could not fall out ; this precaution, for some people, is advisable.

"All ready, so they gave the signal to the windlass on the south side, and I felt the endless rope tightening and pulling up the slack, and slowly out the pulley ran.

"The precipice is so steep on the north side that after five yards of one's journey you are hanging over a 100-ft. depth, and after thirty yards over the rushing water 400 ft. below—more than the height of St. Paul's Cathedral. It was a novel experience and one well worth feeling, as the eye finds it is so difficult to give a correct impression of the height—the stereoscopic effect is not great enough in looking downwards (a most unusual direction) ; but as the 'boys' working at the bridge hurled down huge boulders and stones I then noticed that the long time taken for these to reach the water below me was much more startling than when seen from the opposite side. No downward motion can be discerned, only the dwindling of the rock in size, due to the perspective effect, as it falls lower and lower before reaching the water with a report like blasting and a splash more than

THE GORGE OF THE RIVER ZAMBESI, VICTORIA FALLS.
Mr. C. Beresford Fox crossing the Gorge for the first time on the wire rope, Nov., 1903.

[To face p. 178.

50 ft. in height. I found myself quite relieved when directly over the water, with no prospect of falling on to a rock in the event of the rope breaking.

"After the first few moments there is a real charm in looking down; nothing but space between you and the water, save for the 'sag' of the returning endless wire; the small trees and even the large ones on the south ledge bearing such a different appearance below.

"Of course the predominant thought is, what would one feel if the pulley broke, whether you would really be unconscious after the first 100 ft., and whether that last jerk you felt isn't the cable snapping; and you hurriedly look down to see if the water and rocks are not rushing up to meet you in your downward flight, and are relieved to see the cable still intact and stretching in a graceful curve to either side of the gorge.

"Such a comfortable sensation too, on a sagging rope—a smooth, gliding motion, and but for the slight vibration caused by the pulley running over the separate strands, more like that of a boat, with a steady rise and fall, and perhaps a slight swinging of the chair from side to side.

"This journey of 300 yds. through the air saves

a detour of 9 to 10 miles by land and river, and gives a good idea of the splendid view which will be obtained from the bridge, when completed, of the superb scenery."

"Excavation for bridge is getting on slowly only, owing to the impossibility of getting 'boys'; there is also such a great deal of cleaning down of the sides of the cliff, to get rid of loose boulders, that the work has been increased in amount. Of course on the north side the *débris* you clear away falls into the water below, but on this side it falls 80 ft. and then rolls, and will mostly have to be shifted again, unavoidably too, owing to the ledge of rock.

"What erratic courses falling boulders take! You start a large one from the top—probably it breaks, and the pieces go in all directions within 45° of its original course; but often the whole boulder on landing takes an entirely new route, and goes crashing through the brushwood beyond the 60-ft. clearing, and away over the ledge at least 100 ft. to the right or left of where it started.

"All these boulders and *débris* falling into the water have attracted enormous tiger-fish, which from time to time play on the surface of the swirling backwater directly below the bridge:

From a Photo by] [*F. W. Sykes.*

VICTORIA FALLS OF THE RIVER ZAMBESI, AS VIEWED ACROSS THE "BOILING POT."

Height 400 ft., length of "lip" of fall 4,000 ft.

[*To face p.* 180.

bream about 18 in. long, and awful-looking barbel about 4 ft. 6 in. to 5 ft., like serpents. I've written off to Bulawayo for some especially large hooks and strong cord; and before long I hope to have some fun fishing from the ledge below, or from the cable above, as it is as yet impossible to get down to the water's edge.

"The bush and the trees are so beautifully fresh and green with the late thunderstorms and rain, the grass is all sprouting up, and the many lovely flowering trees give such an exquisite scent as you ride by, that you often pull up and wonder where the scent is coming from, so small in many cases is the blossom—tuberose is not in it! Ground flowers are not out yet, but the beauty of this place is charming.

"I am putting up some fifteen or twenty huts for the railway company, or for the men and boys, *e.g.* a bedroom hut (all circular), 13 ft. or 14 ft. diameter inside, about 7 ft. or 8 ft. walls, and a sloping conical roof; another 12 ft. high. It is made of poles cut out of the bush, and placed close together all round save for doors or windows. The roof is then thatched with good grass, and the walls and floors 'dargha'd,' *i.e.* plastered with clay, hiding the poles completely; and then

you have a delightfully cool and waterproof dwelling.

"Then, again, a mess hut is 15 ft. to 18 ft. diameter inside, and has a 5-ft. verandah all round, with perhaps a light trellis-work balustrade. The floor inside and on the verandah is dargha ; but the main walls are poles 12 in. apart, and covered inside and out by long $\frac{1}{2}$-in. diameter reeds, placed side by side perpendicularly, so that the air, cooled by the verandah, filters through these reed walls, and keeps the whole place delightfully fresh.

"Heavy thunderstorms are hovering around, dark blue hills over other side of river; huge, magnificent 'Alpine' clouds and brilliant sunshine making colour and contrasts so glorious. I am in excellent health and in a healthy spot, high up on the sand-belt, and a mile and a half from the bridge. The roar of the falls upsets conversation, and the river is rising. I've painted a 40-ft. gauge down below on the rock, and already 3 ft. have been submerged."

Within a month of writing the above letter an accident happened to the writer which might have cost him his life. He had found it necessary to climb down to the water's edge at a spot

From a Photo by] [*F. W. Sykes.*

VICTORIA FALLS OF THE RIVER ZAMBESI.

View of the Gorge across the "Boiling Pot" and "Danger Point," with the Falls in the distance.

[*To face p.* 182.

which hitherto had never been reached, and on his return he realised that the overhanging cliff would require the aid of a rope to be surmounted. A rope was therefore thrown down to him, having been made fast to a tree at the top, but unfortunately it had been dragged through wet grass and, what was worse, through a large greasy fungus. Of this he was ignorant, and having climbed up eighty feet, and to within six feet of the top of the cliff, his hand grasped this crushed fungus which enveloped the rope. Immediately his grip was gone and the rope was lubricated, with the result that he slipped down its entire length, some eighty feet, and fell off at the end, a depth of some twenty feet farther, being providentially caught in the fork of a tree. No bones broken, but wrists and ankle sprained, and back bruised, and his life was saved; but it took six hours before they were able to rescue him and place him in safety at the top of the ravine, by which time it was pitch dark, and great difficulty was experienced in finding the ropes. The last operation was to hoist him up by rope and pulley 110 ft.; and in connection with this he wrote, "I had often wished to experience a long swing—suggested by the movement of candelabra suspended

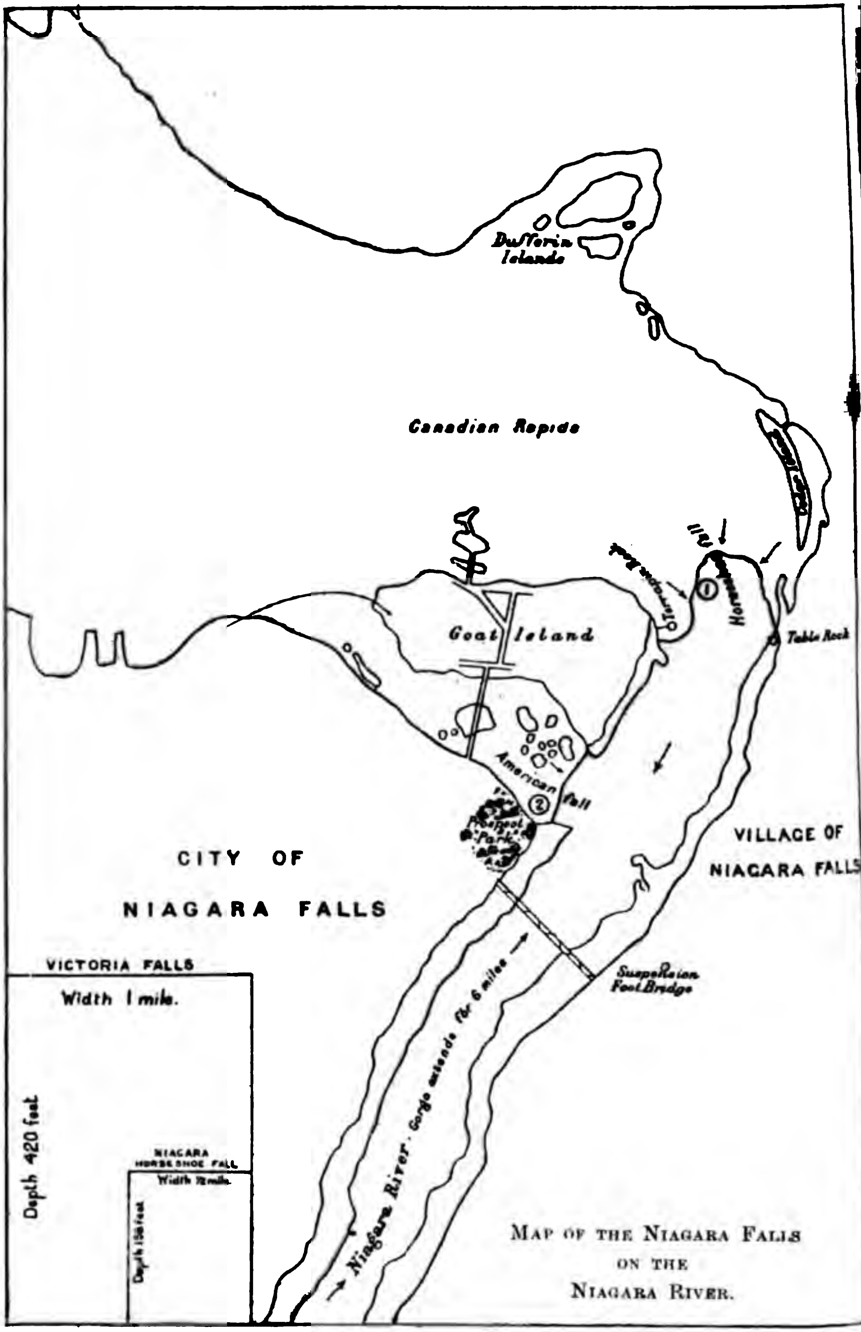
from the roof of a cathedral; and I attained my desire—a pendulum 110 ft. long with an oscillation of 40 ft. from side to side, with a period of about ten seconds: moreover, I enjoyed it."

The bridge is expected to be completed early in 1905; but meanwhile a rope-way, worked electrically, is being provided, by which the various portions of the bridge for the north side can be transported across the gorge, and in addition a mile of permanent way can be delivered every day, so that the construction of the railway can be pushed ahead towards the Copper Mines (some 350 miles) without waiting for the actual completion of the bridge.

Professor Koch, the well-known German scientist, and who was for some time in this neighbourhood, gave my son his advice as to the best method for staving off malarial fever. He told him to have good food, but little stimulant, and instead of taking a daily dose of sulphate of quinine, as is generally done in tropical climates in feverish districts, to take fifteen grains of the hydrochloride of quinine only once in the week. So far this treatment has been completely successful, and I mention it for the benefit of future travellers.

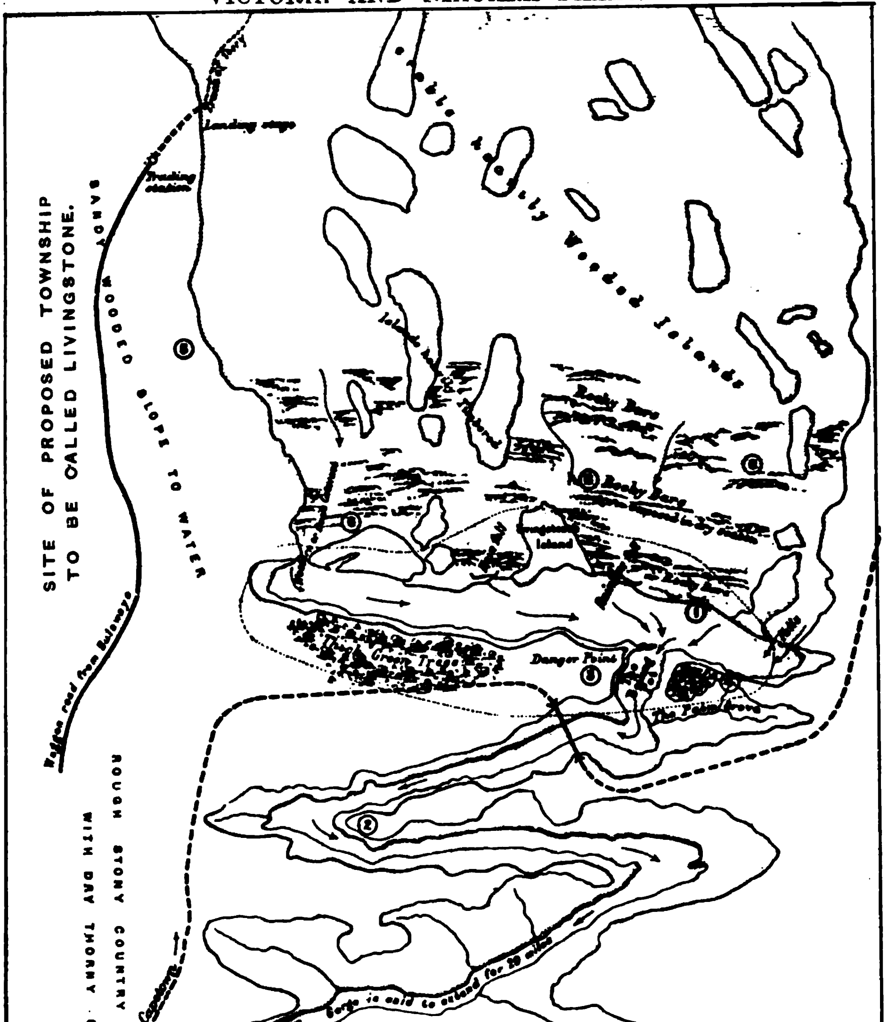
The following short article from *Country Life*

COMPARATIVE PLANS OF THE



1. Height of Perpendicular Cliff at this point 158 ft. 2. Height of Perpendicular Cliff at this point 167 ft.

LIGHT BLUE, Water above Falls. BUFF, Foreshore.
DARK BLUE, Water below Falls. GREY, Surrounding Country.



Map of the Victoria Falls.

1. Height of Perpendicular Cliff at this point 420 ft. (Mansergh). 2. Profile cliff. 3. Level green grass. 4. The Knife Edge. 5. Giese's Store, 500 yards up stream. 6. Rocky bars, nearly hidden at full water (June).

Light Blue, Water above Falls. Buff, Foreshore.

of January 23rd, 1904, may induce some enthusiastic gardeners to visit the falls in search of plants.

"A NEW BULB FROM RHODESIA

"The Cape has always been known as being very prolific in all kinds of bulbs. It is only necessary to mention such plants as the Arum Lily, both white and yellow, the Crinum, Gladiolus, Freesia, Amaryllis, the African bulb Gloriosa superba, Watsonia, Ixia, Sparaxis, and many others. Farther north, in the valley of the Zambesi, and in the country lying between this and Lake Tanganyika, a still greater variety is to be found, and amongst them many at present unknown to science. A doctor now in London, who has just travelled throughout this region, says that bulbs grow everywhere, even in the foundations of one's house, and many are of the most lovely hues and forms. Hitherto it has been practically almost impossible to transmit them to England, owing to the excessive length of time during which they have to remain in their packages, it being a common occurrence to find that they had started into growth during the journey, and, from want of light and nourishment, had perished *en route*. Now, however, that the

Rhodesia railway has actually reached the Zambesi, it brings all the flora of that vast district, which is under the control of the British South Africa Company, within fairly easy reach of London, packages having arrived in less than four weeks.

"About a year ago Mr. S. F. Townsend, the resident engineer of the railway company at Bulawayo, transmitted to the writer four small bulbs, about the size of crocus roots, which he had succeeded in finding close to the great Victoria Falls, and the name of which was unknown. Immediately in front of the great fall, on the other side of the gorge, exists what Livingstone described as the 'Rain Forest,' so called on account of the fine vegetation at that particular place being in almost perpetual rain, the result of the great masses of spray thrown high into the air by the falls. These great columns of spray are regarded with awe by the natives, who associate the roar of the cascade with the idea that it is 'smoke that sounds.'

"It is the vegetation of this forest that is being so carefully protected by the company's engineers from any injury due to the construction of the railway, so that not a single tree will be touched and all the amenities of the falls will be jealously guarded. Mr. Townsend was wet through to the

From a Photo by] [*F. W. Sykes.*

VICTORIA FALLS OF THE RIVER ZAMBESI, FROM THE WESTERN END.

Height 400 ft.

To face p. 186.

skin in securing these roots, and on their arrival in England it was a matter of some difficulty to assimilate the treatment to what they had been accustomed to in their native habitat. They were grown in a stove-house and kept syringed several times a day. In November and December they flowered, throwing up five spikes of bloom of a lovely yellow tint. One of these was sent to Kew, and Sir W. T. Thiselton-Dyer, after examining it, wrote, 'It seems to us quite unique, and a brilliant discovery; it ought to be the starting point of a new race of garden gladioli.' Later examination seemed to show that it is closely allied to Gladiolus primulinus (Baker); meanwhile, it has been named Maid of the Mist (Townsend). Mr. J. W. Barr, of Surbiton, came to see it in bloom, and expressed much interest in it—it being unlike anything he had previously seen. The remarkable thing about it is that it can grow and flower in such incessant rain, but the petals are so arranged as to form a kind of umbrella for the protection of the pistil and stamens."

On the north side of the river is Barotse Land, the extensive territory under King Lewanika, the enlightened sovereign, and who was recently

in England. It is in his domains that the great copper deposits exist, 350 miles north of the falls, and which are said to be amongst the richest copper mines in the world. The railway is to be at once extended to them, and this will form another important link in the through line.

One is often asked how soon the railway will be completed between the Cape and Cairo, but this is not easy to answer. It may be many years; but, on the other hand, a rapid through communication is quite within measurable distance.

Lake Tanganyika being 400 miles in length, a railway there is unnecessary, as commodious steamers will be placed on the lake, and the same remark applies to the other two lakes and the Nile. Thus out of a total distance of 5,611 miles, no less than 1,800 miles will be performed by steamer, leaving 3,811 miles to be accomplished by rail, and of this distance 2,770 miles are already built. In other words, only 1,041 miles of railway remain to be constructed to get through communication, and as 350 miles of this are to be built shortly to reach the copper mines, only 700 miles will then have to be accomplished.

The great scarcity of cotton at present existing

in the world compels attention to other sources of supply, and it has been proved that the vicinity of the Victoria Falls not only grows excellent cotton and tobacco, but the vegetables produced here are hardly equalled by any other part of the world.

CHAPTER XII

CONCLUSION

Some few years ago I was in Cairo, and met Colonel Williams, an American who had been sent out by the Brussels Conference to investigate and report upon the questions of the supply of firearms and liquor to the native races of Africa. He had gone round the entire coast-line of that continent, had visited every colony, except two of the least important, had studied the administration of government in the colonies belonging to Great Britain, France, Italy, Germany, Spain, Portugal, Russia, Turkey, had been in Egypt, Morocco, Liberia, and various native states, such as Damaraland and Somaliland, had then ascended the River Congo from its mouth up to the Tanganyika Lake, whence he had travelled eastwards and came out at Mombasa. Thence he returned *viâ* the Red Sea to Cairo, where I met him on his way to America. He was coming to stay with me in

England, but I saw at once he was very ill from the privations and exposure on his long journeys, and he died soon afterwards, much to the regret and loss of all who knew him.

In conversation I asked him what were the conclusions at which he had arrived as regards the success or non-success of the colonisation of Africa, and his answer is worth recording.

He said that the British colonies were the only ones which were prospering, and, on pressing him for an explanation, he gave four reasons for their success, as compared with the others.

1. Free trade, and non-remittance of revenue to the mother country.
2. Light taxation and collection of customs only to the extent required for the maintenance of the colony.
3. Establishment of schools and education, and the fair and kindly treatment of the natives.
4. The introduction of the Bible, and of Christian missionary work.

In his opinion, and after his long journeys, he had come to the conclusion that the open Bible was urgently wanted in all lands; and this was

corroborated by Mrs. Bishop (*née* Miss Bird), the well-known writer and traveller in India, China, Japan, and elsewhere, who described the frightful state of things existing in Mohammedan and uncivilised lands, the degradation of woman, and the slave trade, and who pleaded that Christianity was the only cure for the "open-sore" of these countries.

Engineers in the execution of great works visit all parts of the world, and I would ask them to do all in their power to uphold the truth. It is, I am sure, unnecessary to appeal to them to maintain our national honour, or to conduct themselves as gentlemen, for no Englishman worthy of the name would be found wanting in these virtues; but I would ask them to go much farther than this—to use their influence to suppress drink, to protect the honour of women and the innocency of children, to maintain the observance of Sunday or the Lord's Day, to encourage all true missionary work, and to sympathise with the missionaries themselves, who in consequence of many and great difficulties, are frequently liable to be depressed and cast down.

The following remarks by that fine Scottish artisan-missionary, Robert Mackay, of Uganda, will

encourage us all in such work. He wrote on November 19th, 1878: "It is no sacrifice, as some think, to come here as the pioneers of Christianity and civilisation. I would not give up my position here for all the world. A powerful race has to be won from darkness to light; superstition and idolatry have to be overthrown; men have to be taught to love God and to love their neighbour, which means the uprooting of institutions which have lasted for centuries; labour made noble; the slave set free; knowledge imparted and wisdom implanted; and above all that true wisdom taught which alone can elevate man from a brute to a son of God. Who would not willingly engage in such noble work and consider it the highest honour on earth to be called to do it?"

Admiral Sir Harry H. Rawson, K.C.B., some time after the Benin expedition, told me that he estimated the number of deaths by crucifixion, which were caused by the King of Benin, to be many thousands annually, and that, although this had been stopped, yet it was only necessary to go another one or two hundred miles farther north to find the same state of things still existing. So there is ample scope still remaining for the influence of Christianity to be brought to bear upon these

heathen nations, for where the Bible is, there is Liberty.

Then, to come nearer home, as regards the treatment of the clerks and assistants who are engaged in offices in London and other cities and towns, employers would do well to consider the possibility of a weekly holiday. No one can say that the lives of these workers are too enviable; and consequently, anything that can be done to brighten them, and at the same time to contribute to their physical health and stamina, is worthy of consideration. They necessarily often lead very unnatural lives, spending long hours in dimly lighted offices, with but few opportunities for exercise and bodily recreation; and even their Saturday afternoons, which they are supposed to have to themselves, are, excepting in summer, of but small help to them. Most offices close at one o'clock on Saturdays, and then the clerks have to get home and have their dinners, by which time it is three o'clock before they can join in football or hockey, bicycling or cricket.

A suggestion was made by a friend some three years ago, which we adopted in our office with most satisfactory results. The body of clerks divide themselves into three parties: once every

three weeks one-third are allowed to absent themselves from their duties from 5.30 p.m. on Friday until Monday morning. This enables them to get into the country on Friday night, and secures to them the whole of Saturday and Sunday with their friends, returning to work on Monday; and if by reason of distance they come somewhat late on Monday, this is permitted. The remaining two-thirds of the clerks, knowing that their turn is coming, voluntarily and willingly do the work of the absent third, in addition to their own; and the result is more than satisfactory. They come back on the Monday fresh and well, and in good and grateful spirits, and we have never experienced the smallest inconvenience in our business. The two days' holiday which they get every three weeks in the country conduces to their health and happiness, and also cultivates the kindliest of feelings between employers and employed.

I strongly recommend this system to the consideration of all firms, and men of business, as it is a concession which can be made without sacrifice on their part. It is of immense benefit to their employés, and of great importance to the health and manliness of the workers in our great cities.

I desire to say a few words upon the relations which ought to exist between masters and men, and which, if adopted, would tend to diminish, to a great extent, the present strained attitude which unfortunately predominates. Labour to-day, with honourable exceptions, is not as conscientious as it should be. Although many men, in all the different branches of labour, work loyally and well for their employers, it is to be feared that the majority work with the desire only to obtain their wages with a minimum of effort, and that as soon as the clock strikes (and in many cases *before* it strikes) they throw down their tools and take themselves off, no matter how important it may be that the particular work upon which they are engaged should be completed before the day's employment closes. I have known cases in which thousands of pounds have been jeopardised for want of an extra half-hour's labour, and the men, although knowing this, nevertheless have left the work unfinished. When remonstrated with, and the prospective loss pointed out to them, their reply has been, "So much the better for trade."

This state of things should not be possible; the men should take a deep and honourable interest in the work they have in hand, and although proper

remuneration for their labour should be secured to them, this should not be the only point for their consideration. They should be taught by their trades-union leaders that conscientious and good work is what is required, and that all "scamped" and jerry work is an unpardonable sin.

The trades-union leaders should encourage, and not oppose, profit-sharing with the masters, and they should abrogate all false regulations. At present a good, a bad, or an indifferent workman receives the same rate of pay, and all stimulus to improvement is strangled. All restrictions as to the amount of work to be done by a man in a day should be removed, strict punctuality and discipline should be enforced, and then England would be in a fair way to regain that position in the manufacturing world which, alas! she is rapidly losing. One has only to visit the splendid and orderly establishments of America, and Germany, to see that we are being beaten in the race, and that it is imperative that a drastic change should come over both masters and men in this country, if we are to retain our supremacy.

I say masters as well as men, and say this advisedly. Were the masters to cultivate a kindly and personal—not patronising—interest in their

men; were they to have more of the "milk of human kindness" in their relations with their employés; were they to disregard that oppressive rule of supply and demand as regards wages; and were they to see that labour was properly remunerated,—then the labour machinery of this land would work far more smoothly. On the one hand, labour should be truthful and enthusiastic; on the other, capital should be generous and sympathetic.

In conclusion, may I say that we engineers are making use of, and earning our livelihood by utilising, the great powers of Nature which God has given us; let us therefore be honest and generous enough to obey the injunction of the writer of the Proverbs when he says:

> In all thy ways acknowledge Him,
> And He shall direct thy paths.

ADDENDA

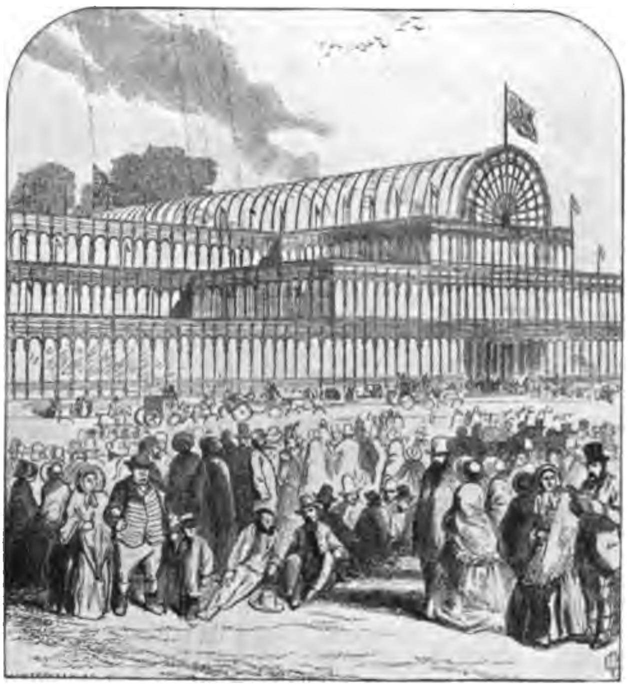
THE

CRYSTAL PALACE

THAT

FOX BUILT

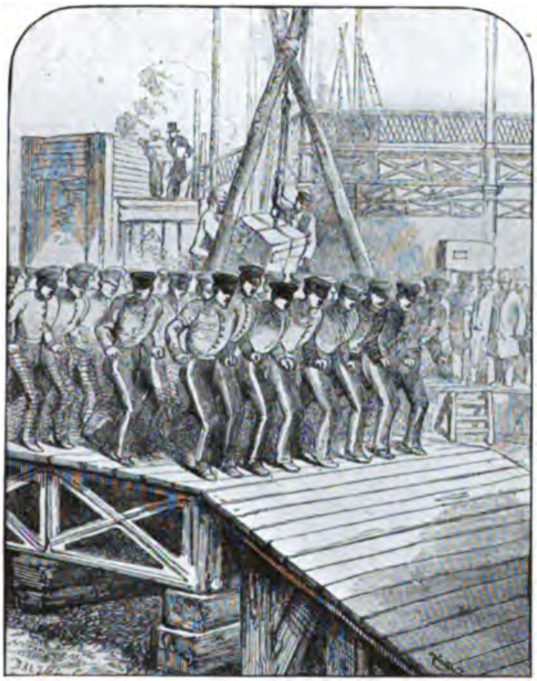
A PYRAMID OF RHYME



"THIS IS THE PALACE THAT FOX BUILT"

THE WORKMEN

These are the Workmen, a busy array—
Two thousand and more, as I have heard say,
Who readily, steadily, toiled away,
And finished before the first of May
THE CRYSTAL PALACE
THAT FOX
BUILT.



THE SAPPERS AND MINERS

These are the Sappers and Miners who ran
To test the girders on Paxton's plan;
And helped the Workmen, that busy array—
Two thousand and more, as I have heard say,
Who readily, steadily, toiled away,
And finished before the first of May
THE CRYSTAL PALACE
THAT FOX
BUILT.

THE EXHIBITORS AND VISITORS

These are the natives of different lands:
From Siberia's snows and the African sands,
The American States and Ind's coral strands,—
Who were drawn all together in brotherly bands,
Not in battle to strive, but in love to shake hands,—
And who freighted the steamers, the ships, and the trains,
The drays and the barrows, the trucks and the wains,
With the wonderful goods,—a most infinite store,
Of ebony, jewels, gold, silver, and ore;
An ivory throne, and a malachite door;
The diamonds of Spain, and the famed Koh-i-noor;
Mosaics from Rome; and a carved escritoire;
Fans of cobweb and feathers, of leaves and of straw;
And cottons and silks, both woven and raw;
And wondrous machines, I can't tell you what for;
And implements,—aye, by the dozen and score,
For farming, and weaving, and printing, and war;
And fountains of glass, never seen heretofore;
And statues to rival the sculptures of yore;
And trophies with lace and rich silk covered o'er;
And tap'stry and velvets, and many things more;
Piled over the gall'ries, and counters, and floor,
By the Sappers and Miners, who marched and who ran
To test the girders on Paxton's plan;
And helped the Workmen, that busy array—
Two thousand and more, as I have heard say,
Who readily, steadily, toiled away,
And finished before the first of May
THE CRYSTAL PALACE
THAT FOX
BUILT.

THE SHIPS, STEAMERS, AND TRAINS

These are the steamers, the ships, and the trains,
The drays and the barrows, the trucks and the wains,
With the wonderful goods,—a most infinite store,
Of ebony, jewels, gold, silver, and ore;
An ivory throne, and a malachite door;
The diamonds of Spain, and the famed Koh-i-noor;
Mosaics from Rome; and a carved escritoire;
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Two thousand and more, as I have heard say,
Who readily, steadily, toiled away,
And finished before the first of May
THE CRYSTAL PALACE
THAT FOX
BUILT.

THE QUEEN AND THE ROYAL CHILDREN

This is the Queen, who went in state
On the opening day,
The first of May,
One thousand eight hundred and fifty-one,
With her eldest daughter and eldest son,
And all that were noble, and learned, and
great— [narrate ;
And a crowd of the million no tongue can
And was met, as she passed through the
Colebrookdale gate,
By her Consort the Prince, from whose
wisdom and weight
This Congress of Peace and World's Fair
emanate ; [Magistrate ;
And the Royal Commission ; and Chief
And Executive Triad, who settled the rate
And order of entrance, duration, and date,
And all questions to ways and to means that
relate ;
Fox and Henderson too on her Majesty wait,
Who contracted to build this vast crystal
estate ; [Fête ;
And Paxton who planned it,—for Industry's
And the principal natives of different lands,
From Siberia's snows and the African sands,
The American States and Ind's coral
strands,— [bands,
Who were drawn all together in brotherly
Not in battle to strive, but in love to shake
hands,—
And who freighted the steamers, the ships,
and the trains,
The drays and the barrows, the trucks and
the wains, [store,
With the wonderful goods,—a most infinite
Of ebony, jewels, gold, silver, and ore ;
An ivory throne, and a malachite door ;
The diamonds of Spain, and the famed Koh-
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Mosaics from Rome ; and a carved escritoire ;
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of straw ; [raw ;
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And wondrous machines, I can't tell you
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And fountains of glass, never seen hereto-
And statues to rival the sculptures of yore ;
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To test the girders on Paxton's plan ;
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Two thousand and more, as I have heard say
Who readily, steadily, toiled away,
And finished before the first of May
THE CRYSTAL PALACE
THAT FOX
BUILT.

II

MAGIC SQUARES

THE subject of magic squares is fully described in "Mathematical Recreations and Problems," by Professor W. W. Rouse Ball (Macmillan); but having studied the question carefully and made out a rule for myself for their construction, it may be interesting for one's readers to know how to make them, although I cannot say what the explanation is.

x

17	24	1	8	15
23	5	7	14	16
4	6	13	20	22
10	12	19	21	3
11	18	25	2	9

We will take squares with an unequal number of divisions on each side—say, 3, 5, 7, and so on; and I will endeavour to describe the method, by first drawing a square with five divisions in length and five in depth, making twenty-five smaller squares. We draw an arrow at 45° angle, and in

this direction we have to work; in other words, we must regard the squares as so many steps on a staircase.

We find *three* rules to apply.

1. When a figure goes outside, above the top line, drop to the bottom.
2. When a figure goes outside to the right, commence again on the left-hand side, one line higher up.
3. When a figure is stopped by another, place it *beneath* the figure which blocks the way.

We begin by placing 1 in the middle of the top line, and endeavour to go upstairs. The next figure, 2, would naturally go where a small x is given, but as that is outside the square it cannot be, so we drop to the bottom of that column; 3 is the next step, and 4 would go where a dot is placed. This is inadmissible, so we shoot horizontally to the other end of the line; 5 follows as a matter of course, and 6 would go on the square already occupied by 1, which of course cannot be allowed. Therefore, under the third rule, 6 goes under 5; 7 and 8 follow; 9 would go outside, and therefore drops to the bottom: 10 would go outside,

and therefore is placed at the other end of the line; 11 is stopped by a number, and consequently goes under 10; 12, 13, 14, 15 follow the usual rule. But now a difficulty arises: 16 would go outside the square, and can neither drop down to the bottom nor go to the end of the line, as both positions would be outside the square. Consequently it must be treated as stopped by a number; 17, 18, and all other figures up to 25 follow the rules as given, and the square is complete.

One very peculiar feature of this square is that each column or line added up, whether vertically, horizontally, or diagonally, comes to 65.

Again, any five figures taken symmetrically produce the same result. Thus, taking the centre figure 13 in all cases, you can select any two squares (such as 1 and 16), and then taking the other two squares which are symmetrical (in this case 25 would correspond with 1, and 10 with 16) the total of these five figures, $1+16+13+25+10=65$.

Or, as another illustration, take 14 and 16, the corresponding figures would be 12 and 10: these added together with $13=65$.

The next square to be described is one with four on each side. We place 1 in left-hand corner, and work in the direction of the top arrow, filling in

the four corners and the four middle squares first. Thus 1 finds its place; 2 would go into the next square, and 3 into the next; but these are not written in, as we must fill the corner and centre squares first; but 4 finds its resting-place. 5 is not written in, but 6 and 7, being some of the centre squares, are filled in. 8 is left out, also 9, which desires to come in on the third line; but 10 and 11 are provided for. 12 is left out for a time, but 13 and 16 occupy the corners.

1	15	14	4
12	6	7	9
8	10	11	5
13	3	2	16

We now have to fill in the remaining squares, and this we do by starting from the bottom right-hand square and working leftwards in the direction of the bottom arrow. 1 endeavours to go into the first square, but it not only is already occupied by 16, but it has already been used. 2 comes next, 3 next, and, following the same rule, 5 and 8; 9 and 12, 14 and 15 find their places.

Columns vertical, horizontal, or diagonal all make a total of 34. Any four figures symmetrical round the centre of the figure do the same, *e.g.* the four corners, or the four centre squares, or

12 and 15 and 2 and 5, or 15 and 14 and 3 and 2 all produce the same result. Again, if we imagine the square of sixteen spaces to be divided into four of four each, such as:

1	15
12	6

or

14	4
7	9

each group of four yields the same total of 34.

The move of the knight in chess does the same, commencing say at 9 and going to 15, 8, and 2, the result is 34. Or commencing at 5 and going to 14, 12, and 3, the same result obtains.

But any one who desires to go more deeply into the subject is advised to study the book already referred to.

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